Popular Astronomy.

Vol. XXVII, No. 4. APRIL, 1919. Whole No. 264

METEORITES AND METEORS.

WILLIAM H. PICKERING.

The former are of two kinds, meteoric irons and meteoric stones. The difference between them is fundamental, not only in chemical composition, but also in their orbits prior to striking the earth. The meteoric stones are sometimes known as aerolites, and in this article to distinguish them from the meteoric irons we shall call them by that name. Very rarely aerolites have fallen which contained large quantities of iron, seeming thus to be a connecting link with the meteoric irons proper. The only one of these of whose orbit we have any knowledge, was that which fell at Estherville in 1879. It followed a course showing no marked peculiarity to differentiate it from that of an ordinary stony meteorite.

Still another very curious difference between the aerolites and the meteoric irons is that while the former are distributed between the eastern and the western hemispheres pretty closely in proportion to the relative area of the land occupied by civilized peoples, the latter are found in very great excess in the western hemisphere. In fact there are nine times as many meteoric irons, in proportion to the aerolites, found in the western hemisphere as there are in the eastern. The irons usually have fallen in the past, while the aerolites generally were actually seen to fall. The only plausible explanation of this preference for the western hemisphere seems to be that most of the irons must have fallen on a single day, when we came into collision with a slowly moving meteor shower, or comet, moving in a direct orbit,—in short one of Jupiter's family of comets. Since many of these irons are found on the surface of the ground, the collision must have been fairly recent, probably since the Christian era (Popular Astronomy 1909, 17, 273).

An objection to this suggestion has been raised that the American irons are of many different types of chemical composition, while in the case of a single fall all the specimens are of the same type. It must be remembered however that it is not a question in this case of a single fall, but of a great many different falls, all occurring on the same day. In other words there is no reason why the meteors coming from different portions of a comet several hundred miles apart should be exactly alike.

Meteors, a name applied to bodies which seldom reach the earth's surface, are of varying brightness, from the insignificant falling star to fireballs, objects varying in brightness from that of the planet Jupiter to that of the moon in exceptional cases. The usual range of brightness visible to the naked eye extends through ten magnitudes, implying a range of one hundred diameters. The ratio of the weight of a faint meteor to that of a bright fireball is therefore one to a million. In the Astrophysical Journal 1910, **31**, 89, it is computed that the diameter of a meteor of the third magnitude is between 5 and 6 centimeters. The assumption is there made that the meteor is a solid body. This though natural enough clearly does not follow, since it might be either gaseous or liquid. A recent computation implies that it is the former, and the results are sufficiently striking and unexpected to be given in a little detail.

By H. A. **61**, 69 we find that one candle power is equal to a zero magnitude star at a distance of almost exactly one-third of a mile. A meteor of the third magnitude at 100 miles would therefore give out a light of 5700 c. p. If we consider the light to be of the same color as a carbon filament heated to 2000° C, the temperature will be approximately the same. At that temperature we are able to produce electrically 300 c. p. per horse power. The meteor is therefore delivering to our atmosphere energy at the rate of 19 h. p., or 73,000,000 foot grains per second. Let us assume that it is traveling at a rate of 25 miles, or 132, 000 feet per second. Then its kinetic energy will be equal to $132{,}000^2 M/64 = 73{,}000{,}000$ foot grains. Hence M, the weight of the meteor, will be 0.268 grains.

Since the meteor is of practically the same color and brightness all along its course, and moves with a nearly uniform speed, it must distribute its mass at a fairly uniform rate. Moreover since the average meteor lasts for about one and a half seconds, we must multiply this mean weight by 1.5, giving us for the weight of the average meteor visible to the naked eye, at the moment that it enters our atmosphere 0.402 grains or 26 milligrams. This value does not differ greatly from earlier estimates, but the fact that this small mass should be delivering 19 horse power, even for a short interval, seems surprising. A fireball

of the brightness of Jupiter, if it lasts three seconds, will weigh seven pounds. The diameter of a meteor of the third magnitude, when solid, before entering the earth's atmosphere, is 0.075 inches or 1.90 millimeters.

Let us now consider what its size must be while shining with a brilliancy of 5700 c. p. Iron vapor is four times as heavy as atmospheric air, therefore whatever the bulk vaporized at any given instant might be, if it were composed of air only, its weight would be one-quarter of 0.268 or 0.067 grains.

Its temperature we have assumed to be 2000° C, or 2273° absolute. At ordinary temperatures the same bulk of air would weigh 2273/273=8.33 times as much, or 0.558 grains. Since a cubic inch of air at ordinary temperatures weighs 0.327 grains, the volume of the gaseous meteor must be 1.706 cubic inches, and its diameter, if spherical, 1.48 inches, equivalent to 3.76 centimeters. This result, although obtained in an entirely different manner, and in one which is much more accurate, agrees sufficiently well with the earlier estimate above mentioned of from 5 to 6 centimeters.

Fireballs move with various velocities, and have been classified as swift, slow, and very slow. The last of these are comparatively rare, and are the source of the aerolites. While sometimes incandescent in the air, they generally cool and become quite invisible before striking the ground, the thud of their fall being the first announcement of their arrival. They are often cool enough to be handled immediately, and in one instance, at Dhurmsala in India, in 1860, the stone was said to be found covered with frost when discovered. The smaller ones are in one instance known to have landed on thin ice without cracking it.

They fall either as single masses, in two or three pieces, or as showers of small stones. The explosions sometimes heard are doubtless due to the heating of occluded gases, but fractures must frequently be due to unequal heating, combined with the force of the blow produced by striking our atmosphere. The rumble and roar sometimes heard, and sometimes said to be terrific, is more often due to their rapid rush through our atmosphere. The stone moves faster than a sound wave, the wave breaks, and the noise is analagous to the breaking of an ocean wave on a beach. It is much the same thing as the crack of a whip. If a high velocity shell fired from a distance passes near an observer, and does not explode, two explosions are nevertheless apparently heard. The first is the noise made by the passage of the shell, and the other the concussion of the gun. The wellknown whining sound of a shell in mid air is an entirely different phenomenon, and due to unbroken sound waves.

Although so many meteorites have reached the Earth's surface in past times, yet we have only two fairly authentic accounts of anyone having been killed by one. The first is in the first historical mention of the phenomenon, and is contained in the Book of Joshua, chap. x, verse 11, describing Joshua's battle with, and defeat of the Amorites. "And it came to pass, as they fled from before Israel, and were in the going down to Beth-horon, that the Lord cast down great stones from Heaven upon them unto Azekah, and they died; they were more which died with hailstones than they whom the children of Israel slew with the sword." If this statement is true, we might be led to suspect that the childred of Israel either were not very expert swordsmen, or else that as compared with the Amorites they were not very swift of feet. We have here clearly two very different and contradictory accounts of the episode. Either great stones fell from heaven, in other words aerolites, in which case they certainly were not hail, or else we have a violent hail storm, in which case the projectiles were not aerolites. The two diverse accounts each mutually injure the evidential value of the other.

It seems probable however that we have here a true account of a rather interesting fall of aerolites, and that the early chroniclers' or translators' fear of telling something improbable, and something which would not be believed, that great stones should have fallen from heaven, led them later to try to explain away the miracle, and as a result to tell something which if not impossible, was at least more unlikely, namely that men should have been killed by hailstones. It is also interesting, though perhaps not surprising, that the fall of real stones from heaven should have appeared to them more improbable than the wellknown unbelievable astronomical events described in the next two verses. Apparently a man was really killed by a meteorite at Mhow in India in 1827.

Much of the original data for the following discussion are taken from Popular Astronomy 1909, **17**, 273, and 1910, **18**, 262, where the facts will be found given more in detail. Most of the falling stars, 64 per cent out of about eight thousand recorded by Mr. Denning (M. N. 1880, **50**,410), omitting all the August Perseids, fell in the *last* six months of the year. Most of the aerolites, 56 per cent out of 253 recorded in the Catalogue of the British Museum for 1896, fell in the *first* six months. More than twice as many meteors are seen after midnight as before. Of the aerolites on the other hand 57 per cent fall between noon and midnight. This is not due to the fact that few people are up after midnight, because by far the greater number of meteorites are seen to fall by daylight. Between seven in the morning and one in the afternoon 51 were recorded, while between one and seven at night we find 75 out of

169. Falling stars therefore predominate on the side of the earth advancing in its orbit, while aerolites predominate on the rear side.

The iron meteorites strike us with high velocities when they reach the earth at all, and sometimes land white hot. Only nine were seen to fall in the last century. The mean eccentricity of the orbits of six of these has been computed, and found to be 0.56. The mean eccentricity of the orbit of Jupiter's comets is 0.64, of Holmes' comet 0.41. The iron meteorites therefore follow cometary orbits. There is no reason to question but that they are simply ordinary meteors, which from their superior size and unusually slow speed have survived to reach the earth's surface. Indeed one of them was seen to fall in Mexico during a shower of the Andromedids which follow Biela's comet.

If most of the ordinary meteors follow parabolic orbits, their velocities are 1.41 times that of the earth. If associated with Neptune's comets their velocities are 1.39, if with Jupiter's they move with 1.30 times our velocity. Let us assume that the meteors are all moving in parabolic orbits parallel to that of the earth at the moment of encounter, and that all the orbits are direct; then all the meteors would fall before midnight, on the following side of the earth. If equal numbers of the orbits are direct and retrograde, then six times as many would fall after midnight, on the preceding side of the earth, as on the following side, the formula being $(1.4 + 1.0)/(1.4 - 1.0)$. According to Denning over twice as many fall after midnight. This would appear however to be very much of an understatement. A very brief investigation made in Jamaica in spare moments, in the first four months of the year 1912, showed that 75 zenith meteors came from the east to 18 from the west, a ratio of 4.2. The search was made in general between 8^h and 10^h in the evening, a time which would distinctly favor the western meteors (Popular Astronomy 1917, **25**, 635). This search would render the ratio of 6 to 1, for meteors observed at or about midnight, not improbable, thus implying an equal number of direct and retrograde orbits.

In a tabulation of meteoric radiants computed by himself, Olivier found 26 direct to 150 retrograde swarms (Trans. Amer. Phil. Soc. 1911, **22**, Part I, 5). It would therefore appear that there are also six times as many retrograde as direct meteoric showers, and this well-known excess has always been a puzzle to those astronomers who were interested in cometary orbits, since the orbits of comets of long period are about equally divided as to their direction, and the orbits of those of short period are all direct. In order properly to determine a radiant, a certain number of meteors must be observed within a certain brief interval of time, and the number of radiants determined will therefore be more or less proportional to the number of meteors observed. The loca-

tion of the radiant is an important factor in the computation of an orbit, and the same formula will therefore apply to the orbits as to the numbers of meteors observed. It would therefore appear probable from Olivier's results also, that if the orbits of all meteoric showers could be known, we should then find about equal numbers of them direct and retrograde, a rather unexpected result.

Although both of these investigations lead to the same conclusion, there is nevertheless a modifying influence to be noted, and that is that the observations were not uniformly distributed throughout the year. In H. A. **61**, 202, is given a list of the longitudes of the aphelia of all the comets of class A, those that are associated with the planet Jupiter, that had appeared up to January 1, 1910. Of these there were 34, and it is found that half of them are located within the 80° extending from longitude 158° to longitude 238°, that is their perihelia extend from longitude 338° to 58°. The smallest of these perihelia is 0.68 units, and the largest 2.14. If many of these meteors that we observe are associated with these comets, and other invisible ones that have similar orbits, we should expect to be overtaken by them most frequently when the earth was passing from longitude 338° to 58°. This will occur between September 1 and November 21, mean date October 11. According to Denning the six months extending from July through December, mean date October 1, furnish nearly twice as many meteors as the remaining six months of the year.

We should accordingly expect to find direct orbits, and meteors coming from the west more often in the latter part of the year than in the earlier part. The writer's observations were made from January to April inclusive. Olivier's observations were made almost exclusively in the latter half of the year, but they were made on only 37 different dates out of the 365, and many of these were dates when the Perseids and Leonids were especially frequent. Both of these great showers are retrograde. It accordingly appears that our observations of meteoric orbits, if properly interpreted, instead of indicating a majority as being retrograde, would lead us to believe that there are at least as many that are direct, and had the observations been uniformly distributed throughout the year, they might even have indicated a majority of direct orbits.

An evident reason why so few iron meteorites are able to get through our atmosphere, and reach the ground, is on account of their high velocities. They are burned up before they can land. The slow moving aerolites however are much more frequently seen to fall, and instead of nine cases being observed in a century, we find on the average about three in a year. These fall on perhaps two per cent of the earth's entire surface. Many are never found even there, and Farrington

computes that about 900 must reach us every year. Out of 169 areolites the times of whose falls are known, 96 fell on the following side of the earth, between noon and midnight, and 73 on the preceding side. The ratio is therefore about 4 to 3. In order to reach the earth's surface they must all of them have been moving in direct orbits, and if their speed was much greater than that of the earth, practically all would have fallen on the following side. Indeed only those whose paths crossed the earth's at a considerable angle could have reached the preceding side.

On the other hand if their mean speed in their orbits was identical with that of the earth, their falls would have been uniformly distributed on both sides of it. If some of the orbits were inclined to the ecliptic, rather more would fall on the preceding side. Since rather more actually fall on the following side, it is clear that their mean speed must be somewhat, but not greatly, in excess of that of the earth. Since their orbits differ considerably among themselves, it is clear that many of them are moving more slowly than the earth, and that these orbits are therefore smaller, approaching us only at their aphelia.

Even if coming from an average asteroid their speeds would be 1.22 times that of the earth,—a wholly impossible figure for those which we overtake. From this it follows that a considerable proportion of them cannot formerly have been parts of either an asteroid or a comet, and that their origin is therefore distinctly different from that of the iron meteorites, whose derivation appears to be clear. In a subsequent paper we shall give our reason for believing them to be strictly of terrestrial origin, although not volcanic.

Mandeville, Jamaica. B. W. I.
Dec. 25, 1918.

NIGHT.

Thy retinue, the constellations, Night,
With stately march across the heavens go;
And planets shine afar with steady light,
While countless hosts of starry systems show
Within the galaxy, the Milky Way.
The kindly Moon moves graciously along
And turns, O Night, thy darkness into day.
For Queen is she of all the shining throng!
Such wondrous orbs as thou revealest, Night,
Can man yet doubt a Pow'r controlling all?
Long ere these mighty suns have lost their light
What scenes and changes shall our souls enthrall?
Unharmed 'mid wreck of Time shall they not stay,
Till thou, O Night, art merged in Endless Day?

ALICE BERLINGETT.

Norfolk, Virginia.

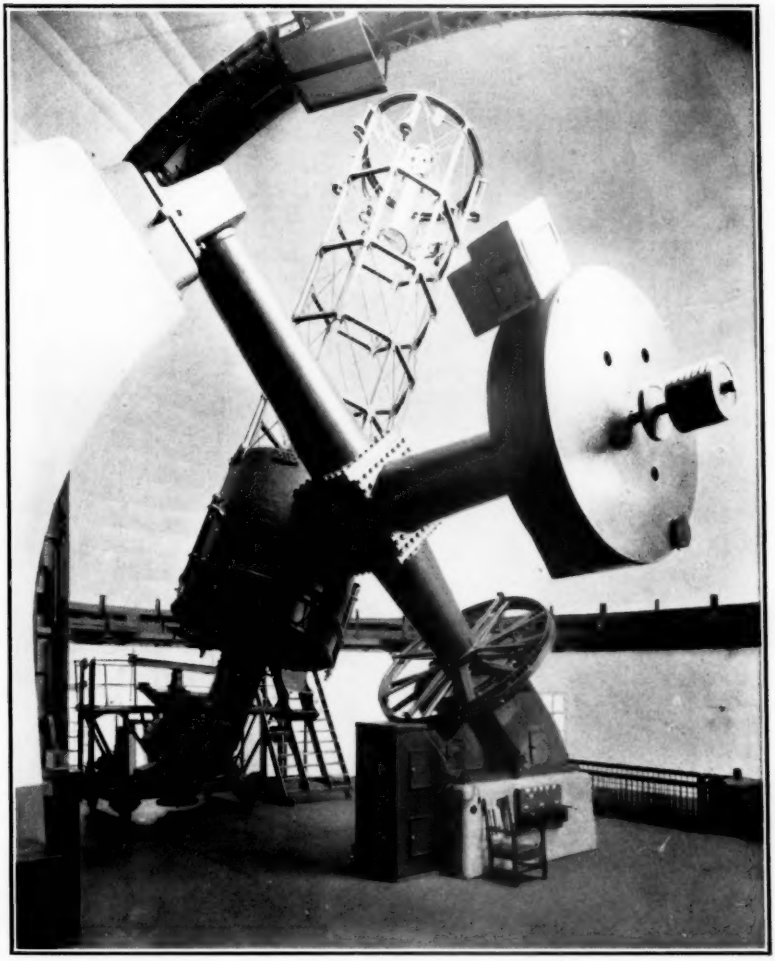
THE 72-INCH REFLECTING TELESCOPE OF THE DOMINION ASTROPHYSICAL OBSERVATORY, VICTORIA, B. C.

The following account of the 72-inch reflecting telescope which is now in use in the Dominion Astrophysical Observatory at Victoria, British Columbia, is taken largely from the accounts by Professor J. S. Plaskett which appeared in the October, 1918, number of the "Publications of the Astronomical Society of the Pacific" and the "Journal of the Royal Astronomical Society of Canada." We are indebted to the courtesy of the latter journal for the use of the cuts which illustrate this paper.

The Dominion Astrophysical Observatory is located on Observatory Hill, 730 feet above sea level, about eight miles north of Victoria, B. C. It was planned especially for research work and particularly to extend the excellent work, which has been done in the measurement of the radial velocities of stars at the Dominion Observatory at Ottawa, Canada, since 1905, to fainter stars than could be studied with the aid of the 15-inch refractor. Professor J. S. Plaskett had charge of the plans for the observatory and the telescope and is now the director of the observatory.

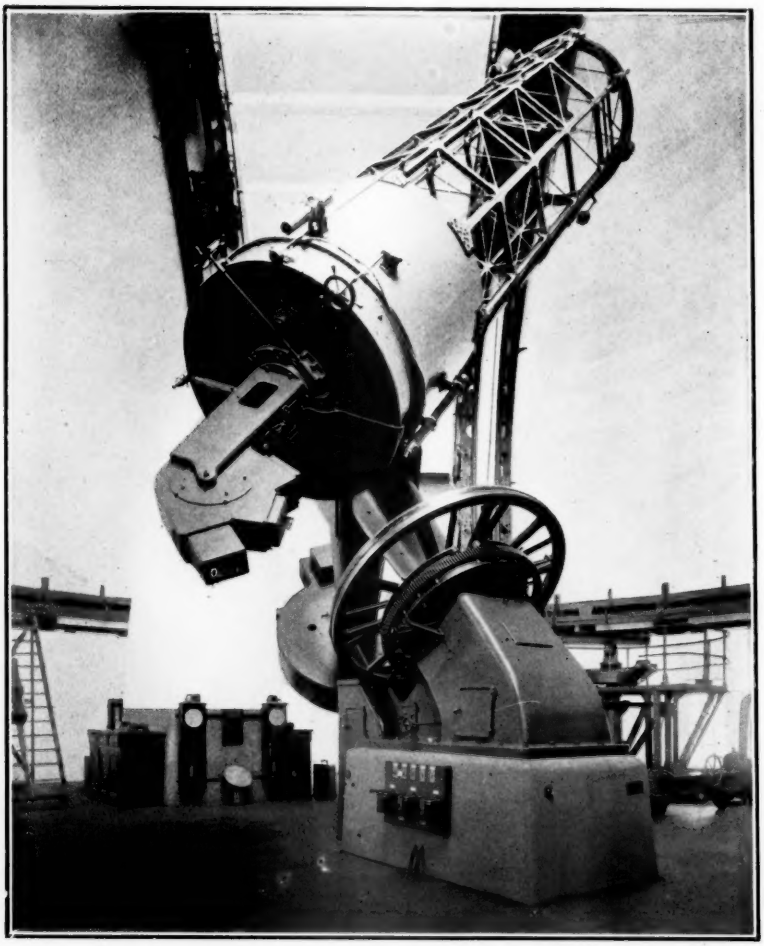
The contracts for the telescope were let in October 1913, to the John A. Brashear Co., of Pittsburgh for the optical parts, and to the Warner and Swasey Co., of Cleveland for the mechanical parts, of a 72-inch reflecting telescope of the latest and best type. Upwards of a year was spent in the design, about a year and a half in the construction and completion of the mounting at Cleveland, and about six months in the dismounting, packing, shipping, and erection at Victoria. In October, 1916, three years after the contract was awarded, the mounting was completed and in place, but the mirror was not finished until April 1918. The observatory building, one residence for an astronomer and cottage for the engineer, were completed in 1916, but owing to war conditions, the office building and other residences which are necessary in the relatively inaccessible position of the observatory were temporarily postponed.

PLATE XIII



THE 72-INCH REFLECTOR, WITH SPECTROSCOPE ATTACHED.

[From the Journal of the Royal Astronomical Society of Canada, October 1918.]



THE 72-INCH REFLECTOR, WITH SPECTROSCOPE ATTACHED, LOOKING TOWARD THE NORTHEAST.

[From the Journal of the Royal Astronomical Society of Canada, October 1918.]

The dome, which was built by the Warner and Swasey Co., is 66 feet in outside diameter, revolving on roller bearing wheels on a circular rail and driven by an electric motor operated from one of the telescopic switchboards at a rate of one revolution in six minutes. It has large double shutters operated by an electric motor, giving a clear opening of fifteen feet which extends six feet beyond the zenith. To prevent the wind shaking the tube of the telescope, two electrically operated canvas wind screens are provided, moving up from the bottom and down from the top of the shutter opening, thus enabling the length of the opening to be limited to the diameter of the tube.

Both the dome and building have a double sheet metal covering, ingeniously united by weather guarding at the junction of the two, so as to allow circulation of the air through openings at the bottom of the building, up between the inner and outer walls of the building, and out through louvres at the top. This is for the purpose of preventing the interior from overheating during the day, while the metal construction permits rapid radiation and consequent quick adjustment to the outer temperature at night.

The observing platform is a specially important feature of the dome, as it travels on curved rails attached to the main ribs of the dome and is maintained in horizontal position by an ingenious differential hoisting arrangement. It can be readily brought by electric motor to any desired height, so as to allow convenient access to the upper end of the tube in any position when the telescope is being used at the principal or Newtonian focus. The platform is about 20 feet long by four feet wide and has two wings, one at each end, which project six feet into the dome and are moved by a hand wheel. The wings are curved so as to permit close approach to more than half the circumference of the telescope tube in any position in which it may be used.

The general design of the mounting of the telescope (as will be seen in Plate XIII) resembles that of the Melbourne 4-foot reflector and the Ann Arbor and remounted Crossley 3-foot instruments, having a long polar axis supported on separate bearings at the ends, with the declination axis near the middle and carrying the tube at one side of the axis, and a housing containing the declination moving mechanism on the other side.

This form of mounting was decided on in preference to the fork type of the 60-inch and double fork type of the 100-inch at Mount Wilson, as offering the advantage of reaching every part of the sky and also greater accessibility of the lower end of the tube for the attachment of the spectrograph, etc.

The tube is in three sections: the central, to which the declination axis is attached, the lower section forming the mirror cell, and the

upper section of the skeleton framework, serving to carry the Newtonian and Cassegrain mirrors and to support the plate holder for direct photography at the principal focus. The total length of the tube is about thirty-one feet, and its diameter 7 feet 4 inches. The flange to which the mirror cell is bolted is 7 feet 10 inches in diameter and the cell is 18 inches deep.

The tube is built in such a way as to insure great stiffness with a minimum of weight. It is of comparatively inexpensive construction, as regular commercial shapes are used. The total weight of the complete tube, including the mirror, is about 15 tons.

The declination axis is 14½ feet long, 16 inches in diameter, with a flange 41 inches in diameter, 4 inches thick, to which the boss on the central section of the tube is securely bolted. It weighs nearly 5 tons and, with the tube, is rotated by a spur gear 8 feet in diameter, keyed to the axis and contained in the circular housing at the outboard end.

The polar axis is about 21 feet long and weighs 9½ tons. After its three parts were bolted together it was placed in a large lathe and all bearing surfaces turned true and concentric. It was never afterwards taken apart, thus ensuring perfectly true bearings.

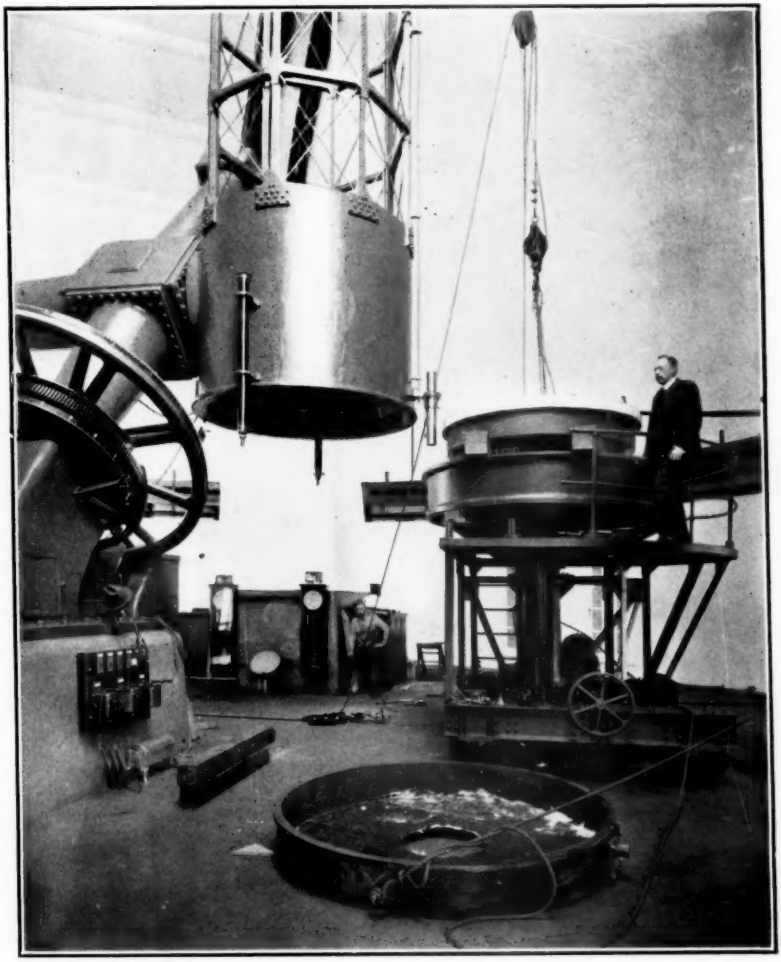
The two supporting pedestals can be well seen in Plates XIII and XVI. The north pier head is in two sections, the upper part, carrying the north bearing of the polar axis, being movable in altitude and azimuth by adjusting screws on the lower part which is bolted to the cement pier. The south pedestal is a substantial casting weighing seven tons and containing within it the quick motion mechanism in right ascension.

The driving clock is in the rectangular case seen in Plate XIII, on the north side of the lower pedestal, from which it is entirely separate. It is supplied with adjusting screws to secure the proper mesh of the worm and worm-wheel after the polar axis is adjusted. It is of the regular Warner and Swasey type, about the same size as the clock of the Yerkes 40-inch telescope, but is original in the method of connection to the worm, which is directly through spur gears and without bevel gears, thus reducing danger of periodic errors.

The driving worm-wheel is nine feet in diameter and weighs about two tons, yet it is so mounted on ball and ball-thrust bearings on the polar axis that it can be moved with the slightest touch. Although it contains 720 teeth, these are so accurately cut that the telescope drives perfectly, without a trace of periodic error even with the 108-foot focus Cassegrain combination.

The glass disk for the mirror was cast and annealed, on the second trial, at the works of the St. Gobain Glass Co., in Charleroi, Belgium. It was completed in July, 1914, and fortunately the Brashear Co. asked

PLATE XV



THE 72-INCH MIRROR HOISTED ON THE SILVERING CAR.

[From the Journal of the Royal Astronomical Society of Canada, October 1918.]

that it be shipped at once, without waiting for the disk of 55 inches diameter, for the testing flat, to be completed. As it was, it left Antwerp only about a week before war was declared and, if it had been held, would probably have been destroyed and the telescope indefinitely delayed, as the glass factory at Charleroi is now in ruins.

The disk, of 73½ inches diameter and 13 inches thick, with a central hole 6 inches in diameter, weighed nearly 5000 pounds. It arrived in Pittsburgh in August, 1914, and grinding operations were at once begun. Three or four months were required in the rough grinding, in the course of which some 600 lbs. of glass were removed, and the disk was reduced to a diameter of 73 inches and a thickness at the edge of 12 inches, the central hole being made true and about 10 inches diameter. The back surface was made nearly flat, the front surface was ground to a section of a sphere of 60 feet radius, since the focal length was to be 30 feet. The front surface was then fine ground to the true radius and both surfaces were polished. Within six months the mirror looked exactly the same as when finished, but it was still far from a perfect optical surface, and it was three years more before the mirror was pronounced ready for installation in the telescope.

Part of the delay was due to the difficulty in getting the disk of glass for the 55-inch flat mirror to be used in testing the large mirror. Efforts to obtain such a disk in America failed and the Brashear Co. had finally to use a 33-inch flat mirror which they already had.

Very considerable difficulties were encountered in the figuring of the large mirror, chiefly on account of temperature changes caused by the polishing and the presence of the central 10-inch opening, which greatly interfered with the regularity of action of the large, full size polishers employed in much of the work. It was found inadvisable to polish more than half an hour at a time, when the glass had to be placed in the testing tube and allowed to stand at least 12 hours before the tests, to determine the effect of the polishing, could be depended upon to give the true reading.

The amount taken off any one part of the mirror by half an hour's polishing was only of the order of one or two millionths of an inch, and to get the curve, which was finally that of a parabola revolved about its axis, to within a quarter wavelength (one two-hundred-thousandth of an inch) of the theoretical form, was an exceedingly difficult and tedious process. The figuring was practically begun during the summer of 1916 and was continued with little intermission for nearly two years, until April 1918. Twice during this interval the surface was nearly right, but scratches appeared or one part of it was polished too deep, necessitating starting again several stages back.

The Cassegrain secondary mirror, 20 inches in diameter, convex on the front surface, was figured in about a week, in connection with the large mirror and the plane.

For shipping the great mirror to Victoria it was left in the strong cast iron cell in which it had been ground and polished, and a strong wooden cover was bolted on top of this cell. This was then packed in a large wooden box with excelsior and it and the other optical parts were shipped by express in a through car to Victoria, so that no transshipment at any point was necessary. It went through without delay, arriving at Victoria six days after leaving Pittsburgh, and was hauled out to the Observatory on the second day following without hitch or accident of any kind. A week later it was installed in the tube, collimated, and the first star spectrum obtained.

Professor Plaskett expresses his great satisfaction in the performance of the telescope, the mounting and the dome, and the character of the seeing, which are all quite equal to and even exceed expectations.

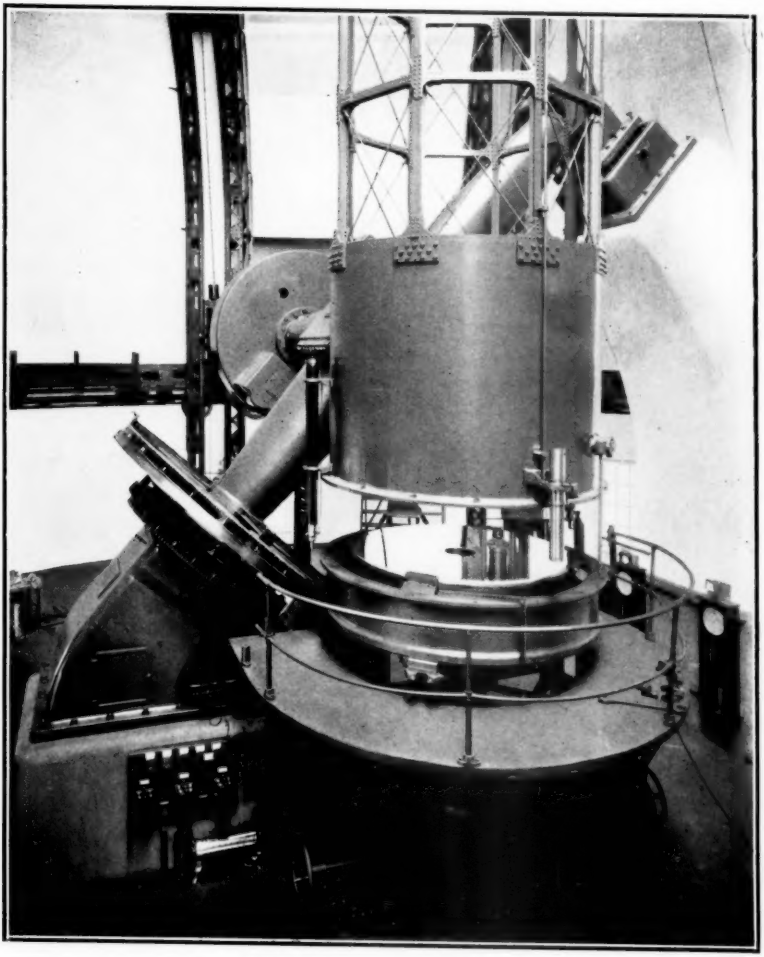
Up to July 1918 the telescope had been used only in the Cassegrain form with the spectrograph, shown in Plates XIII and XIV, attached to the lower end of the tube. The spectrograph here shown is a single prism instrument, which has a linear dispersion at $H\gamma$ of about 35 Angstroms per millimeter and gives excellent spectra of stars of photographic magnitude 7.0 in about 25 minutes, under average seeing conditions.

The telescope is adapted for visual observations at the Cassegrain focus by inserting an auxiliary reflecting ocular adapter, which enables the image to be observed in a convenient position without removing the spectrograph. This is desirable because the latter weighs about 1000 lbs. This adapter is used on Saturday evenings, which have been set aside for visitors to observe with the great reflector.

The mechanism for setting the telescope upon a star, including the electric quick and slow motions and the combined coarse-fine setting circles, works to perfection and, so long as the telescope has not to be reversed on the axis, the time consumed in making the change from one star to another is only from 4 to 5 minutes. Consequently spectra can be accumulated at a rapid rate, 22 spectra of stars averaging fainter than 6.0 magnitude having been obtained on one short summer night.

Plate XV shows the great mirror being lowered into its cell on the silvering car, designed by the Warner and Swasey Co. Professor Plaskett is standing on the car by the side of the mirror.

Plate XVI shows the mirror in its cell, ready to be attached to the telescope. Notice the reflecting power of its polished surface.



MIRROR AND CELL READY TO ATTACH TO TELESCOPE.

[From the Journal of the Royal Astronomical Society of Canada, October 1918.]

A STUDY OF THE CYCLES OF ENCKE'S COMET.

DAVID A. BLENCOE.

There are several cycles respecting the periodic perturbations and secular inequalities of the planetary and satellite orbits that are quite well known and may be found in any good textbook on Astronomy. The Saros was well known to the Chaldeans, and the Metonic Cycle was discovered about four centuries before Christ, but most of the cycles were found by the great galaxy of theoretical astronomers from one-half to two centuries ago. So far as I am aware cycle study of the elements of the orbits has never been taken up with regard to the periodic comets (except in P. A. March 1914, p. 191, where a cycle of periods for Halley's comet is given by the writer). The reason has undoubtedly been the paucity of data, but there are now enough data regarding several of the comets to give preliminary values to these cycles. This is markedly true with Encke's and Halley's, and nearly so in regard to Faye's, Winnecke's, Tuttle's, D'Arrest's, Brorsen's, and Tempel's 2nd, and in a lesser way with several others.

We will here treat of the cycle pertaining to the first named comet, namely Encke's. The data used were taken from Dr. Galle's "Elemente der Cometenbahnen", and the "Astronomische Nachrichten" since 1891, with but few exceptions, namely: the dates of T in 1819, 1881, 1898 to 1914 inclusive, which were taken from Chamber's, Seagrave and other sources. The elements for 1918 are those calculated by Viljev previous to the rediscovery of the comet, and the position of the comet showed that the elements were slightly in error. This will be seen by reference to Plates I and II.

In Table I, P was calculated for the first three apparitions, from the value of μ as given by Encke. In all other cases P was obtained by subtracting Julian dates of perhelion passage. The quantities in ( ) under P denote total number of days in the whole interval and also the average value of the period. All the other quantities in the table are self explanatory, with the exception of P_1, which will be explained later on, $P_1 - P$ being simply the difference between P_1 and P algebraically, taking the value of P from one line above that of P_1.

In Table II a is the semi-major axis, $b = a\sqrt{1-e^2}$ = semi minor axis, $q = a(1-e)$ = perihelion distance, $a(1+e)$ = aphelion distance, $\frac{1+e}{1-e}$ is the ratio of aphelion distance to perihelion distance,

TABLE I.

No. of Return	No. in Element Cycle	T Gr. M. T.	T Julian Date	P Days	P Years	P_1 Days	P_1-P Days	μ	π	Ω	i	e
1	11	1786 Jan. 30.88	2373413.88	1198.37	3.281023			1081".4292	156° 38′ 00″	334° 08′ 00″	13° 36′ 00″	0.84836
2	12	89		(3611.57		1212.79	−14.42					
				1203.86)								
3	13	92				.67						
4	14	95 Dec. 21.45	2377025.45	1201.82	3.290469	.55		1078.3225	156 41 22	334 39 22	13 42 30	0.84883
5	15	1799				.44	−10.62					
				(3622.06								
				1207.35)								
6	16	1802				.33						
7	17	05 Nov. 21.51	2380647.51	1202.52	3.292379	.22		1077.6975	156 47 10	334 20 10	13 33 30	0.84618
8	18	09				.10	− 9.58					
				(4815.45								
				1203.86)								
9	1	12				1212.00						
10	2	15				1211.89						
11	3	19 Jan. 27.26	2385462.26	1212.71	3.320290	.78		1068.6390	156 59 47	334 33 18	13 36 56	0.84862
12	4	22 May 23.97	86674.97	11.31	.316459	.66	+ 1.05	69.8725	157 12 19	25 09	20 21	451
13	5	25 Sept. 16.28	87886.28	11.47	.316902	.55	− 0.34	69.7317	15 06	27 30	21 28	493
14	6	29 Jan. 9.75	89097.75	10.24	.313525	.44	+ 0.03	70.8219	17 28	29 32	20 38	467
15	7	32 May 3.99	90307.99	09.38	.311171	.32	− 1.08	71.5805	21 36	32 10	22 12	545
16	8	35 Aug. 26.37	91517.37	10.65	.314655	.22	− 1.84	70.4561	24 04	35 00	21 19	507
17	9	38 Dec. 19.02	92728.02	10.01	.312898	1211.11	− 0.46	71.0244	27 39	36 42	21 32	522
18	10	42 Apr. 12.03	93938.03	15.58	.328153	1210.98	− 0.97	66.1146	30 01	39 11	20 30	483
19	11	45 Aug. 9.61	95153.61	04.48	.297753	.88	+ 4.70	75.9400	44 55	19 37	07 39	747
20	12	48 Nov. 26.09	96358.09	04.62	.298141	.77	− 6.29	75.8150	47 48	22 18	08 41	787
21	13	52 Mar. 14.71	97562.71	03.33	.294607	.65	− 6.03	76.9683	51 05	23 42	07 50	760
22	14	55 July 1.04	98766.04	05.33	.300084	.55	− 7.22	75.1825	53 12	26 16	08 05	773
23	15	58 Oct. 18.37	2399971.37	06.88	.304328	.44	− 5.11	73.8024	157 57 01	28 01	04 17	639
24	16	62 Feb. 6.25	2401178.25	06.68	.303776	.37	− 3.69	73.9800	158 01 07	30 58	04 57	670
25	17	65 May 27.93	02384.93	05.69	.301065	.29	− 4.61	74.8625	03 49	32 39	03 51	630
26	18	68 Sept. 14.62	03590.62	00.19	.286011	.22	− 4.53	79.7875	11 19	31 34	06 41	913
27	1	71 Dec 28.81	04790.81	01.18	.288722	.14	− 9.95	78.8975	13 14	34 25	07 24	933
28	2	1875 Apr. 12.99	2405991.99	1200.18	3.285990	1210.06	− 8.88	1079.7950	158 17 13	334 37 00	13 07 20	0.84940

TABLE I—Continued.

No of Return	No. in Element Cycle	T Gr. M. T.	T Julian Date	P Days	P Years	P_1 Days	P_1-P Days	μ	π	Ω	i	e
29	3	1878 July 26.17	2407192.17	1208.43	3.308576	1209.97	— 9.79	1072".4225	158° 19′ 34″	334° 39′ 13″	13° 06′ 37″	0.84915
30	4	81 Nov. 15.60	08400.60	08.04	.307504	.89	— 1.46	72.7707	29 40	34 28	12 53 07	540
31	5	85 Mar. 7.64	09608.64	08.36	.308382	.81	— 1.77	72.4850	32 45	36 56	54 01	578
32	6	88 June 28.00	10817.00	06.99	.304627	.72	— 1.36	73.7050	35 56	38 51	53 06	547
33	7	91 Oct. 17.99	12023.99	05.78	.301315	.64	— 2.65	74.7805	38 47	41 27	54 58	647
34	8	95 Feb. 4.77	13229.77	07.09	.304904	.56	— 3.78	73.6150	42 19	44 51	54 24	623
35	9	1898 May 26.86	14436.86	06.54	.303396	.47	— 2.38	74.1050	45 30	46 43	54 37	639
36	10	1901 Sept. 15.40	15643.40	14.34	.324754	.39	— 2.85	67.2049	158 47 57	48 58	53 38	600
37	11	05 Jan. 11.74	16857.74	05.46	.300436	.31	+ 5.03	75.0658	158 02 39	27 08	35 37	717
38	12	08 May 1.20	18063.20	05.82	.301425	.23	— 3.77	74.7463	05 39	30 18	36 40	758
39	13	11 Aug. 19.02	19269.02	03.87	.296087	.14	— 3.32	76.4875	09 01	29 32	34 32	727
40	14	14 Dec. 5.89	20472.89	1205.02	3.299231	1209.06	— 5.19	1075.4600	10 41	32 14	34 56	747
41	15	1918 Mar. 24.91	2421677.91			1208.98	— 3.96		159 14 37	334 34 50	12 31 50	0.84556

TABLE II

No. of Return	No. in Element Cycle	a	b	q	$a(1+e)$	$\frac{1+e}{1-e}$	A	L	V	$\frac{L}{a}$	$\frac{L}{A}$	$\frac{A}{P}$	$\frac{a}{e}$	K
1	11	2.208035	1.168962	0.334827	4.081236	12.189111	8.108920	10.88112	3.31638	4.927972	1.34187	2.471461	2.60271	0.292674
2	12													
3	13													
4	14	2.212275	1.169551	0.334430	4.090118	12.230139	8.128080	10.89698	3.31168	4.926034	1.34066	2.470188	2.60626	0.292271
5	15													
6	16													
7	17	2.213200	1.179368	0.340424	4.085836	12.002194	8.199850	10.92655	3.31874	4.937142	1.33253	2.490553	2.61543	0.292726
8	18													
9	1													
10	2													
11	3	2.225617	1.191903	0.346061	4.105170	12.211111	8.333780	11.00292	3.31385	4.943772	1.32028	2.509955	2.63539	0.291979
12	4	2.223907	1.189513	0.344861	4.102945	11.862567	8.310667	10.99067	3.31397	4.942058	1.32248	2.505883	2.63206	0.292043
13	5	2.224104	1.190535	0.345470	4.102740	11.897405	8.318540	10.99400	3.31455	4.943124	1.32163	2.507928	2.63310	0.292078

TABLE II—Continued.

No. of Return	No. in Element Cycle	a	b	q	$a(1+e)$	$\frac{1+e}{1-e}$	A	L	V	$\frac{L}{a}$	$\frac{L}{A}$	$\frac{A}{P}$	$\frac{a}{e}$	K
14	6	2.222591	1.186984	0.343502	4.101682	11.875833	8.288120	10.97946	3.31353	4.939936	1.32472	2.501300	2.62889	0.292053
15	7	21543	87757	44184	4.098909	940784	289567	97774	1536	41484	2428	03511	2883	2218
16	8	23098	88062	44092	4.102109	909054	297500	98402	1378	40872	2378	03276	3020	2054
17	9	22310	89014	44836	4.099782	921555	301220	98370	1544	42472	2314	2.505729	3049	2200
18	10	29128	83319	40009	4.118245	11.889081	286800	99327	0311	31646	2660	2.489912	3034	1088
19	11	15538	74689	37050	4.094020	12.112167	176200	92260	1213	29998	3590	79322	1307	2180
20	12	15709	75730	37675	93745	146639	184100	92590	1275	31098	3502	81429	1410	2218
21	13	14128	74432	37145	91109	123361	169200	91690	1356	30562	3635	79567	1183	2331
22	14	16576	80468	40488	92673	134555	220283	94131	1547	36138	3102	90935	1886	2385
23	15	18480	80387	40092	96860	020027	239400	94775	1315	34806	2871	93522	2014	2159
24	16	18233	81668	40942	95518	046305	234780	95020	1445	36454	2975	92533	2109	2260
25	17	17019	70995	34482	99560	012361	155940	91835	0752	24782	3870	70700	1034	1797
26	18	10275	66722	33022	87520	256421	101460	88327	1201	23958	4336	65439	0234	2344
27	1	11488	67113	33051	89930	274020	108620	88865	1091	23666	4285	65583	0359	2223
28	2	10262	67355	33418	87109	280222	105840	88490	1252	24706	4285	2.466789	0292	2351
29	3	20381	85981	43270	97491	12.258200	272840	96900	1323	40146	2590	2.500428	2643	2254
30	4	19903	84391	42354	97454	11.936639	259960	96320	1465	38586	2727	2.497341	2468	2219
31	5	20292	85689	43102	97482	968472	270500	96792	1518	39858	2615	99865	2611	2248
32	6	18613	81268	40624	96600	11.942472	233400	95052	1370	35748	3001	91478	2102	2193
33	7	17131	81330	40928	93330	12.026778	228340	94541	1547	36744	3021	92441	2001	2370
34	8	18735	81616	40820	96660	006432	236280	95187	1383	36082	2971	92144	2141	2198
35	9	18061	82635	41582	4.094550	12.020027	240883	95210	1541	37680	2899	94676	2183	2334
36	10	27613	83578	40447	4.114782	11.987000	282967	98854	0507	32870	2664	91306	2948	1277
37	11	16737	76349	37875	4.095591	12.086417	192200	93112	1202	31184	3430	82155	1537	2134
38	12	17179	77681	38630	95727	121639	203120	93613	1255	32460	3317	84723	1685	2158
39	13	14791	75705	37822	91750	095000	180520	92255	1380	31640	3519	81894	1341	2324
40	14	2.216200	1.183203	0.342279	4.090118	12.112167	8.237920	10.94695	3.31803	4.939510	1.32885	2.496922	2.62100	0.292585
41	15					11.949667								

TABE III.

No. of Return	No. in Element Cycle	No. in Visibility Cycle	$\mathfrak{U}$ Comet in Aphelion	$\mathfrak{U}$ Distance	Date Discovered	Date Last Observed	Duration of Visibility Days	No. Days Discovered Before or after T	No. Days Last Observed Before or after T	Hemisphere favorable for observation	Degree of Brightness	Size
1	11	1	1784.58	4.6°	1786 Jan. 17	1786 Jan. 19	2	— 13	— 11		Telescopic	Large
2	12	2	87.88	— 95.6								
3	13	3	91.18	164.3								
4	14	4	94.48	64.1	1795 Nov. 7	1795 Nov. 27	20	— 44	— 24		f.	s. 5′ diam.
5	15	5	1797.78	— 36.1								
6	16	6	1801.08	—136.3								
7	17	7	04.38	123.6	1805 Oct. 19	1805 Nov. 19	31	— 53	— 2		f. vis. to naked eye	s. 4′ or 5′ diam.
8	18	8	07.68	23.4								
9	1	9	10.98	— 76.8								
10	2	10	14.28	—177.0								
11	3	1	17.58	82.9	1818 Nov. 26	1819 Jan. 12	47	— 62	— 15		Telescopic	v. s.
12	4	2	20.88	— 17.3	22 June 2	22 June 23	21	+ 10	+ 31	S		
13	5	3	24.18	—117.5	25 July 13	25 Sept. 7	56	— 34	+ 22			
14	6	4	27.48	142.4	28 Sept. 16	28 Dec. 27	102	—115	— 13		Vis. to naked eye; 5m	About 90′ diam.
15	7	5	30.78	42.2	32 June 1	32 Aug. 21	81	+ 19	+100	S		
16	8	6	34.08	— 58.0	35 July 22	35 Aug. 6	15	— 35	— 20	N&S		
17	9	7	37.38	—158.2	38 Aug. 14	38 Dec. 16	124	—127	— 3	N	Vis. to naked eye	
18	10	8	40.68	101.7	42 Feb. 8	42 May 22	103	— 63	+ 40			
19	11	9	43.98	1.5	45 July 4	45 July 14	10	— 36	— 26			
20	12	10	47.28	— 98.7	48 Aug. 27	48 Nov. 25	90	— 91	— 1		Just vis. to naked eye	Head 8′ diam.
21	13	1	50.58	161.2	52 Jan. 2	52 Mar. 10	68	— 72	— 4			
22	14	2	53.88	61.0	55 July 12	55 Aug. 16	35	+ 11	+ 46			
23	15	3	57.18	— 39.2	58 Aug. 7	58 Oct. 7	61	— 72	— 11		v. f.	
24	16	4	60.48	—139.4	61 Sept. 28	62 Mar. 12	165	—141	+ 24		v. f.	
25	17	5	63.78	120.5	65 Feb. 13	65 July 23	160	—103	+ 57	S	v. f.	
26	18	6	67.08	20.3	68 July 14	68 Sept. 3	51	— 72	— 21			
27	1	7	70.38	— 79.9	71 Sept. 18	71 Dec. 10	83	—101	— 18		f. nebulosity	
28	2	8	1873.68	180.0	1875 Jan. 26	1875 May 17	4111	— 76	+ 35			

TABLE III—Continued.

No. of Return	No. in Element Cycle	No. in Visibility Cycle	$2f$ Comet in Aphelion	$2f$ Distance	Date Discovered	Date Last Observed	Duration of Visibility Days	No. Days Discovered before or after T	No. Days Last Observed before or after T	Hemisphere favorable for observation	Degree of Brightness	Size
29	3	9	1876.98	79.9	1878 Aug. 3	1878 Sept. 6	34	+ 8	+ 42	S	8th magn.	2′ diam.
30	4	10	80.28	— 20.3	81 Aug. 20	81 Nov. 11	83	− 87	− 4		Just vis. to naked eye	2′ diam.
31	5	1	83.58	−120.5	84 Dec. 13	85 Apr. 22	130	− 84	+ 46		Bright	Small
32	6	2	86.88	139.4	88 July 8	88 Aug. 25	48	+ 10	+ 58	S		
33	7	3	90.18	39.2	91 Aug. 1	91 Oct. 11	71	− 77	− 6			
34	8	4	93.48	− 61.0	94 Oct 31	95 Jan. 22	83	− 96	− 13	N	v. f.	
35	9	5	1896.78	−161.2	1898 June 12	1898 June 15	3	+ 17	+ 20	S	v. f.	
36	10	6	1900.08	98.7	1901 Aug. 6	1901 Sept. 4	29	− 38	− 9			
37	11	7	03.38	− 1.5	04 Sept. 11	04 Dec. 27	107	−120	− 13		Quite bright	
38	12	8	06.68	−101.7	08 May 27	08 June 8	12	+ 26	+ 38	S	v. f.	
39	13	9	09.98	158.2	11 July 31	11 Sept. 24	55	− 19	+ 36		7th or 8th mag.	30′ diam.
40	14	10	13.28	58.0	14 Sept. 17	1914 Nov. 27	71	− 78	− 7	N	7th mag.	18¾′ diam.
41	15	1	1916.58	− 42.2	1917 Dec. 30			− 86				

Shape and Character.

1 Well defined. No tail. Bright nucleus. 4 Round. Badly defined. No nucleus. Slight central condensation. 7 No nucleus. Very bright in center. Tail 3° long. 11 Ill defined. 14 Round. Faint nebulosity. 15 Slightly oval coma. Minor axis of coma toward sun. 17 Coma like a broad parabola. Rather bright nucleus. 20 Had a tail 1° long and a small beard. 23 Difficult to observe. 24 Difficult to observe. 27 Round. No condensation at first; later a fan form. 30 Slightly brighter toward center. 31 Brightly condensed. Faint tail 15′ long. 38 Not seen visually. 39 Quite condensed. 40 Photographs showed a short tail.

TABLE IV.

T	No. in Element Cycle	P	q	e	T	No. in Cycle	P	q	e	T	No. in Cycle	u	P	q	e	T	No. in Cycle	u	P	q	e
												°						°			
1598.0	8	1207.3	.3410	.8458	1697.0	2	1214.5	.3397	.8450	1918.2	15	94	1205.0	.3409	.8475	1786	11	− 64	1204.2		
1601.3	9	07.4	419	68	1700.3	3	12.5	448	55	21.5	16	− 9	07.0	407	59	89	12	−163	4.3	.3368	.8482
04.6	10	02.5	353	86	03.6	4	10.2	441	51	24.8	17	−111	07.2	417	78	92	13	− 3	3.07	.3370	.8469
07.9	11	00.5	329	94	06.9	5	10.3	457	54	28.1	18	152	03.7	373	74	95	14	−105	6.5		
11.2	12	00.3	329	94	10.2	6	11.5	431	47	31.4	1	53	00.3	329	94	1799	15	59	8.0	.3397	.8467
14.5	13	03.5	374	73	13.5	7	11.7	445	49	34.7	2	− 52	00.5	329	94	1802	16	− 45	7.56	.3407	.8472
17.8	14	07.2	416	75	16.8	8	11.7	453	44	38.0	3	−151	02.0	350	89	05	17	−145	6.4		
21.1	15	07.0	409	60	20.1	9	10.3	448	93	41.3	4	113	07.5	420	83	09	18	59	2.5	.3393	.8488
24.4	16	05.0	410	75	23.4	10	05.0	356	77	44.6	5	11	07.3	410	58	12	1	− 45	3.5	.3385	.8490
27.7	17	03.8	387	72	26.7	11	02.1	338	88	47.9	6	− 93	05.0	417	88	1815	2	−145	1202.35	.3352	.8480
31.0	18	05.7	385	76	30.0	12	00.6	446	87	51.2	7	170	04.7	390	69						
34.3	1	05.4	378	71	33.3	13	04.5	378	64	54.5	8	72	05.7	393	72						
37.6	1	14.2	402	60	36.6	14	05.9	406	76	57.8	9	− 32	05.8	386	68						
40.9	3	06.8	416	61	39.9	15	06.6	395	68	61.1	10	−133	10.5	405	62						
44.2	4	07.3	417	62	43.2	16	05.5	404	85	64.4	11	131	07.5	410	63						
47.5	5	05.7	412	63	46.5	17	03.0	370	68	67.7	12	30	06.5	400	66						
50.8	6	07.5	412	55	49.8	18	01.5	364	84	71.0	13	− 74	05.8	400	68						
54.1	7	09.0	431	57	53 1	1	03.1	353	83	74.3	14	−172	06.0	400	63						
57.4	8	08.5	413	54	56.4	2	09.8	377	62	77.6	15	91	05.7	423	62						
60.7	9	08.7	436	92	59.7	3	13.5	463	66	80.9	16	− 12	07.7	415	56						
64.0	10	00.4	336	92	63.0	4	12.1	460	44	84.2	17	−115	07.9	425	91						
67.3	11	01.2	331	93	66.3	5	11.7	460	52	87.5	18	149	00.7	336	93						
70.6	12	00.2	332	91	69.6	6	14.3	453	45	90.8	1	49	00.8	329	94						
73.9	13	05.5	390	63	72.9	7	11.4	460	52	94.1	2	− 55	00.2	329	92						
77.2	14	06.5	410	67	76·2	8	12.0	458	45	1997.4	3	−154	05.5	390	65						
80.5	15	06.8	400	63	79.5	9	13.4	459	61	2000.7	4	110	1206.8	.3413	.8469						
83.8	16	05.4	403	87	82.8	10	10.2	386	56												
87.1	17	02.8	370	85	1786.1	11	1203.5	.3358	.8481												
90.4	18	03.7	376	79																	
1693.7	1	1204.1	.3367	.8476																	

Dates of Perihelion Passage

	J. D.	
1789	2374618.08	May 19.08
92	75822.38	Sept. 4.38
1799	78231.95	Apr. 10.95
1802	79439.95	Aug. 1.95
09	81853.91	Mar. 11.91
12	83056.41	June 26.41
1815	2384259.91	Oct. 12.91
1921	2422885.9	July 14.5
24	24093.5	Nov. 3.5
28	25291.5	Feb. 21.5
1931	2426518.5	June 25.5

$A = \pi a^2 \sqrt{1-e^2}$, area of the orbit in square astronomical units. L denotes the length of the orbit and was computed by the following formula:

$$L = 2a\left[(2+(\pi-2)\sqrt{1-e^2}) - \frac{(e^2+\sqrt{1-e^2}-1)}{\sqrt{3(1+\sqrt{1-e^2})-2e^2}}\right].$$

$V = \frac{L}{P}$ and denotes the velocity in astronomical units per year. It is a singular fact that V^2 almost equals L, and in 1829-1832 it does so exactly.

$$\frac{A}{P} = \pi \sqrt{a(1-e^2)}$$

shows that the area covered in a unit of time is variable in the case of this comet.

$$K = \frac{1}{2a} + \frac{\sqrt{a(1-e^2)}}{a'^{3/2}}$$

is a formula due to Callandreau (P.A. February 1904, p. 121), where K is supposed to be a constant in case of an orbit within that of Jupiter and in the same plane and comparable with that of an asteroid. In this formula, a is the semi-major axis of the comet's orbit and a' the same of Jupiter's orbit. On inspection it will be seen that if a increases in first member of the fraction the value of that part of the fraction decreases and if a increases in second member of fraction the value of the second part of the fraction increases, and if e increases $(1 - e^2)$ decreases and vice versa, in second member. Hence for K to be constant, if a increases e must decrease in a certain proportionate ratio All of Table II depends on P or a and e.

In Table III under ☌ is given the date when comet was in aphelion of its orbit and also the distance in degrees that Jupiter was from the position of comet's aphelion at the time that the comet occupied same. Under Brightness and Size, v = very, f = faint, s = small. These brief descriptions were obtained from various sources, chiefly Tuttle and Chambers.

In Table IV are given the values of P, q, and e as obtained graphically from graphs similar to those shown for P, q, and e on Plate 3 for the returns 1598 to 1786 and from 1918 to 2000, T being calculated by using a mean period of 3.3 years years. U denotes the distance in degrees that Jupiter was from perihelion of his orbit at the time when comet was in aphelion of its orbit. By the aid of the graphs on Plate 3 it will be seen that the values of P, q, and e when U lies between 100° to 180° agree quite well with those for U lying between 0° and 80°, as is shown by the small crosses on the graphs. These graphs were made by platting the true values of P, q, and e as ordinates according to the value of U as abscissas. The values of P, q, and e for the unob-

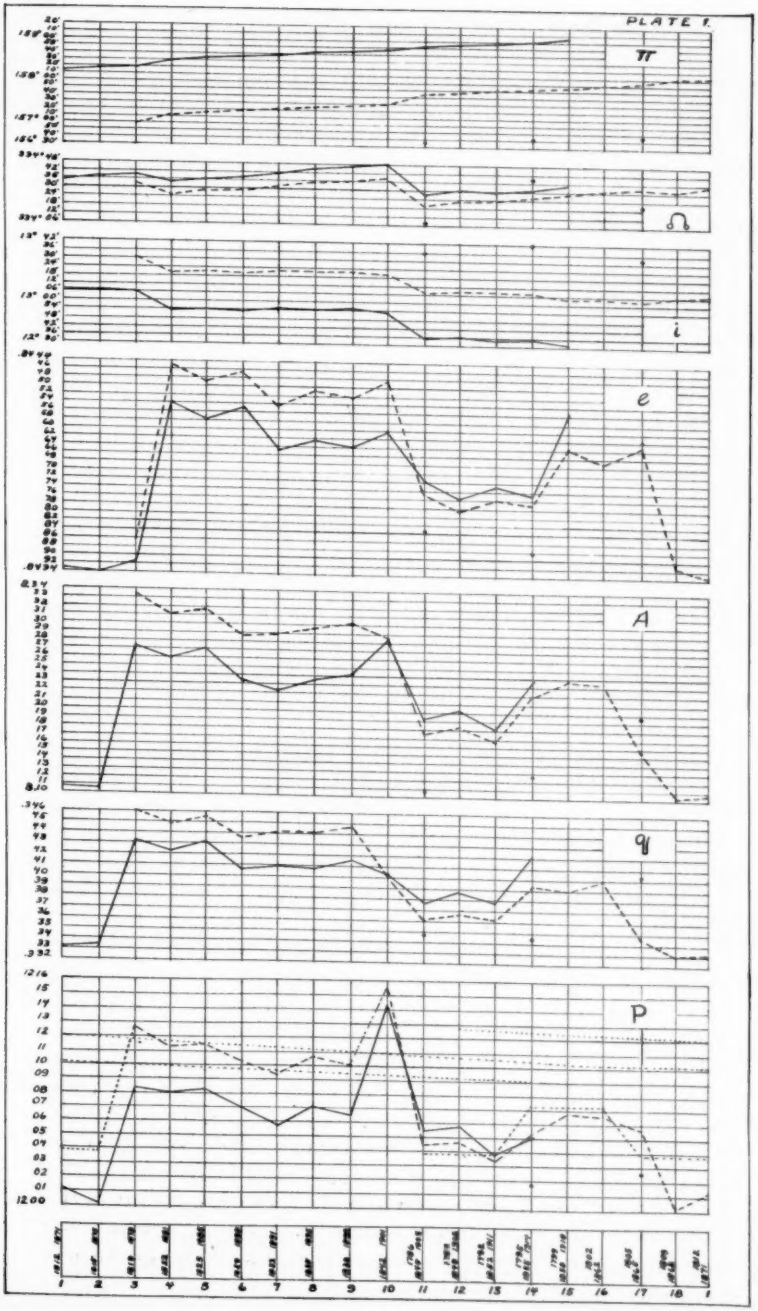


PLATE 1.
π
Ω
i
e
A
q
P

served returns between 1786 and 1819 were obtained by aid of the graphs of Plate 1, the small differences being proportioned and checked by graphs of Plate 3, so that the whole interval of time was used. Dates of perihelion passage T were determined by adding the length of the periods to the Julian dates of the observed returns, etc. In a similar manner were those for the values of T between 1921 and 1931 obtained.

I have taken the values given in the several tables above mentioned and platted them and they show graphically that the cycle for the periodic perturbations of this comet is 18 times that of its orbital period (Plates 1 and 2). It will be seen that its period P, perihelion distance q, and its eccentricity e obey the same cycle. It will also be noted that the marked changes in the inclination i, longitude of ascending node Ω, and longitude of perihelion π also obey this cycle. It will be noted as a rule that q increases and e decreases with an increase in P, while i and Ω show a marked decrease at time of marked increase or decrease in P, and π shows a marked increase under the same circumstances.

On Plates 1 and 2 (except the three upper right hand figures of Plate 2) the light dotted line represents the latter part of the cycle that terminated in 1812; the heavy dashed line represents the cycle 1812-1871 and the solid continuous line the present cycle, which will close in 1931. In platting the graph for the values of P between 1786 and 1819 the average values were used, as I have not been able to find that the length of the periods or date of perihelion passage (or any of the elements) were ever computed, so these are shown by straight lines for the several periods, but in the main it has the same general form as the succeeding cycles. In fact all the elements correspond very closely in the different cycles. In the other elements between 1786 and 1819 the values are shown by a dot, and their cycle correspondence will be noted.

It will be seen that the periods in the first half of the cycle are longer than those of the last part of the cycle. The variation in the period amounts to about 15.4 days, with an average value for the two full cycles ending in 1905 of 1206.774 days, or, for the whole time since 1786 till now, of 1206.601 days. Using the former period, which equals 3.30403 years, we find that 18 times that value gives 59.472 years, while 5 times Jupiter's period gives 59.311 years, and 13 times the comet-Jupiter synodic period of 4.57956 years equals 59.534 years, to which we may add that twice Saturn's period equals 58.915 years. It should here be mentioned that when the value of P was greatest, 1842-1845 and 1901-1905, that Jupiter was nearest aphelion of comet's orbit and when P was least Jupiter was near perihelion of comet's orbit.

PLATE 2

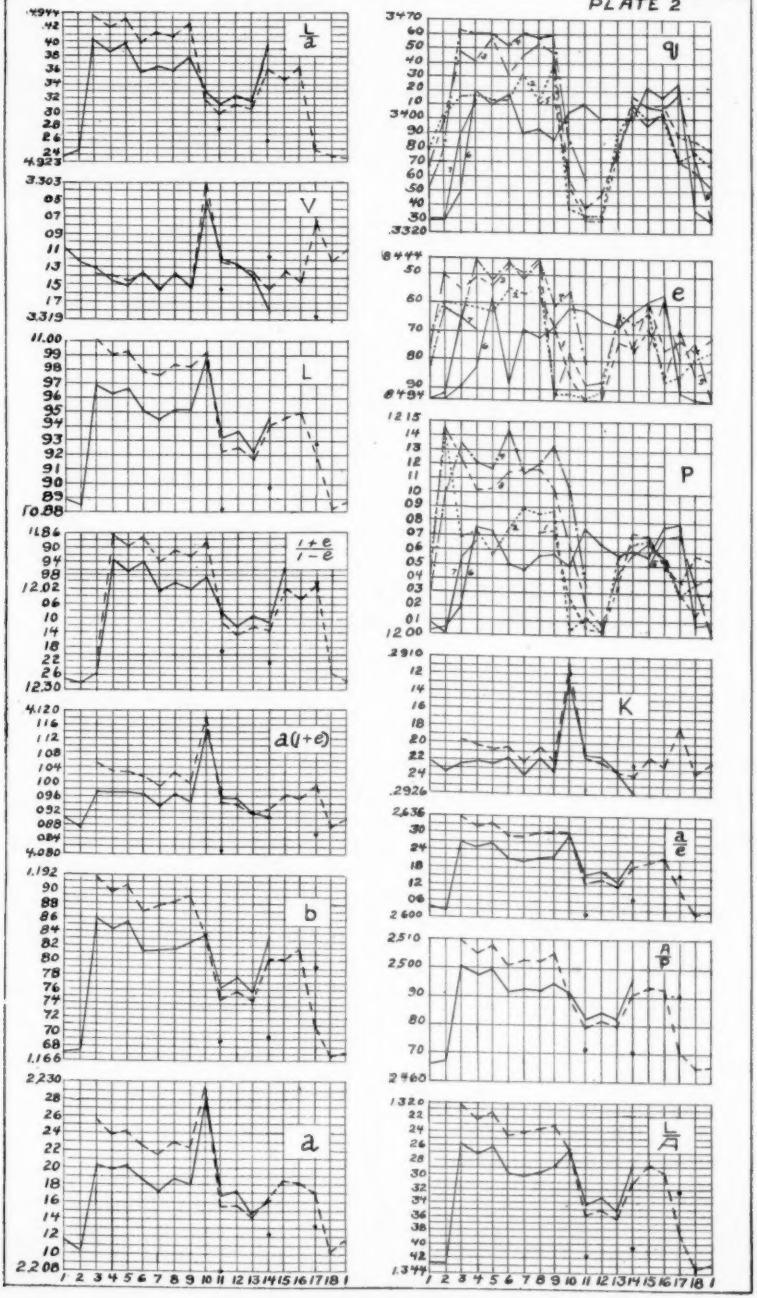
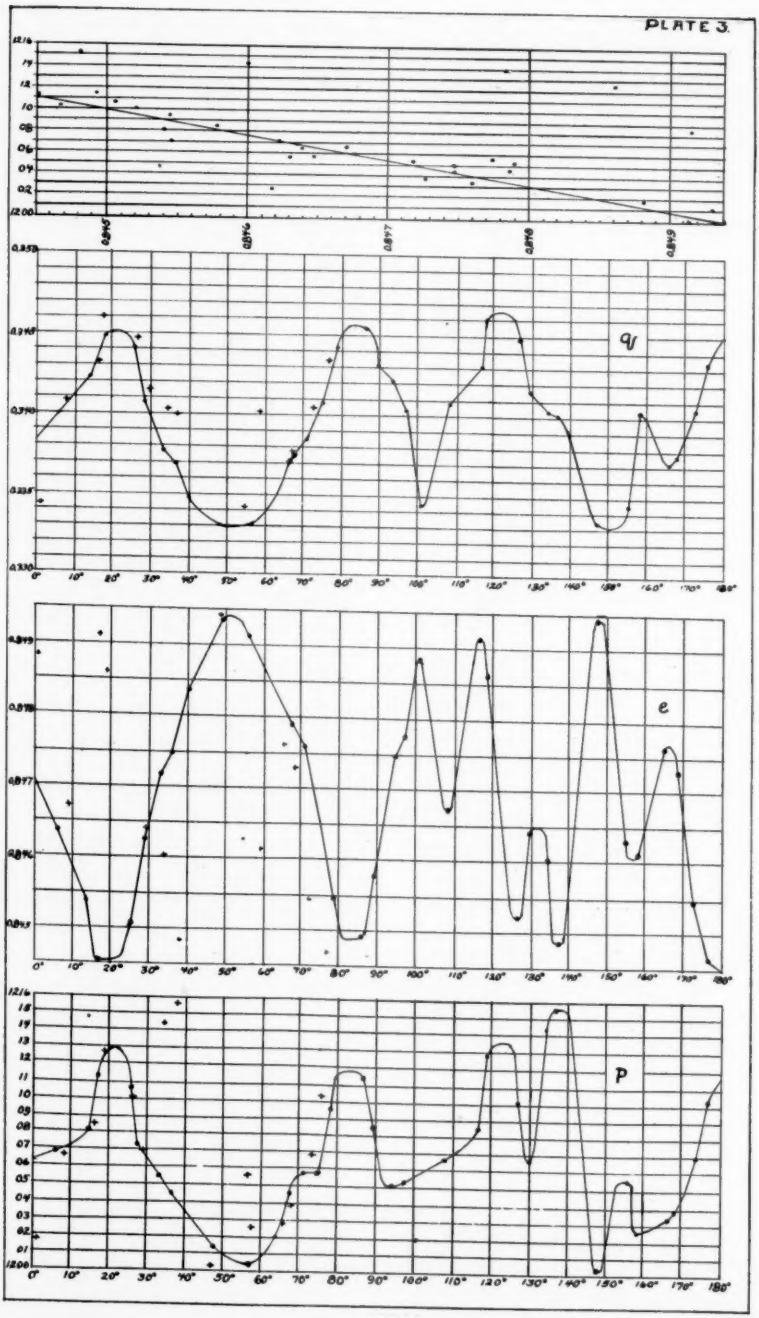

L/a
V
L
(1+e)/(1−e)
a(1+e)
b
a
q
e
P
K
a/e
A/P
L/A
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 1

PLATE 3.



Using mean positions and mean motions of Jupiter and the comet, with Jupiter's period as 11.86 years and comet's period as 3.3 years, I have calculated the distance in degrees that Jupiter is from aphelion of comet's orbit through four complete cycles.

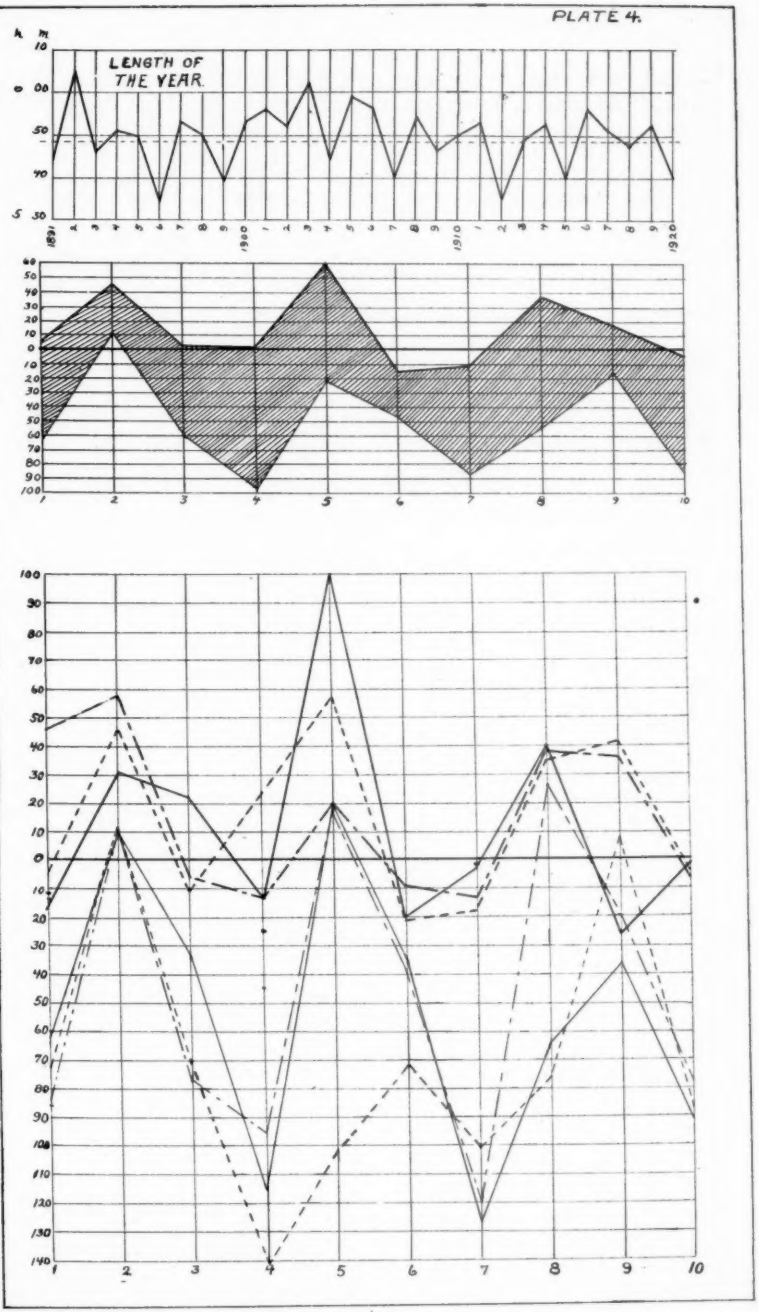
1	2	3	4	5	6	7	8	9
°	°	°	°	°	°	°	°	°
−11	−111	+148	+48	−51	−151	+107	+7	− 92
−14	−114	+145	+45	−55	−155	+104	+4	− 95
−17	−117	+142	+42	−58	−158	+101	+1	− 98
−20	−120	+139	+39	−61	−161	+ 98	−2	−101

10	11	12	13	14	15	16	17	18
°	°	°	°	°	°	°	°	°
+167	+67	−33	−133	+126	+26	−74	−174	+86
+164	+64	−36	−136	+123	+23	−77	−177	+83
+161	+61	−39	−139	+120	+20	−80	−180	+80
+158	+58	−42	−142	+117	+17	−83	+177	+77

It will be seen that Jupiter moves about 100° while the comet makes one revolution and after a cycle it is back to within about 3° of the same position as at the beginning of the cycle, also after eight revolutions Jupiter is quite near comet's aphelion but on the other side, and after about 120 cycles the comet and Jupiter would be back in same relative positions in their orbits. The minus sign denotes that Jupiter has passed the longitude of the aphelion of comet's orbit and plus sign that it has not yet reached it by the number of degrees indicated. A similar table for Saturn shows that it is only 3° from original place after nine revolutions of the comet and 6° at the end of a cycle. Using 3.30403 years as comet's mean period, then 18 times Jupiter's mean yearly motion is not quite 1°.5 greater than five times that of the comet, so that after 241 cycles Jupiter and comet will be back in the same relative positions in their orbits—after a lapse of over fourteen thousand years. Though difference in periods is small the time required in this second value is double that of the first, but does not vitiate the conclusions there drawn. It was a favorite idea of Encke's that the period of this comet was shortening and in *Monthly Notices*, XIX, p. 70 December 1858 (also found in Chamber's Handbook of Astronomy and Watson's Treatise on Comets) he gave the lengths of the periods of the comet from 1786 to 1858 when all the known influences of the planets were allowed for. These are given under P_1 and show a progressive uniform shortening of the comet's periodic time of about 0.11 of a day. I have brought it down to the present time, following statements in Young's Manual (p. 434, 1907 ed.) about its rate of change and when. P_1 is shown on Plate 1 by the very light long dashed straight line. It should perhaps be here stated that these values given by Encke in *Monthly Notices* do not agree with the values derived from dates of perihelion passage as given by him (Table I) and used

in making the graph of P up to the year 1855. If we add together the total number of days for the periods given by Encke from 1786 to 1858 we obtain 26655.34 while the value I obtain from his dates of perihelion passage is 26557.5—nearly a hundred days less. Now 0.11 of a day would amount to about two days in a cycle or 2.4 days during the time under consideration above, and this would not explain the discrepancy. The first gives a mean period of about 2.3 days greater than the latter. In P. A. February 1904, p. 136, is a statement above Seagrave's name that this comet's periodic time has decreased 5 days 22½ hours since 1789. Now in this interval there would be 35 periodic returns or an average shortening of the comet's period of 4.07 hours at each return In P. A. June 1912, p. 390, Seagrave says: "The periodic time still decreases. It has decreased two days and one hour since 1900." This would make 4.08 hours for each return. Young in his Manual (p. 434, 1907 ed.) stated that it was 54 hours shorter then than in 1819. Allowing 24 hours for the interval between 1789 and 1819, according to Young's rate, we have 78 hours against 142 according to Seagrave, a difference of 64 hours that is wholly unaccounted for. It would seem as though something were wrong in their work or theory, as they ought to agree closer than that or we, like the average laymen, will doubt their results and conclusions. (See Newcomb's POPULAR ASTRONOMY pp. 394-395. 6th ed. rev. 1895 for remarks relative thereto.) The 18 returns ending in 1845 are 35.12 days longer than the 18 returns ending in 1905. This would make an average shortening of 1.951 days per each return. Now on Plate 2 in the three upper right hand figures are shown the values of P, q, and e (Table IV) for the intervals 1598 to to 1786 and 1918 to 2000. In these graphs the numbers thereon denote the cycle to which they belong, 1 being the cycle ending in 1631, 2 in 1690, 3 in 1749, 4 from 1749 to 1786, 5 from 1918 to 1928, 6 ending in 1987, 7 from 1987 to 2000. It will be seen by the aid of Plates 1 and 2 that the long periods of years ago (See 2, 3, and 4, Plate 2 under P) did not come at the same phase of the cycle as now, and (by 6) that hereafter the periods on each side of the central one of the cycle are quite well balanced. A study of this graph will show that the period will not keep on shortening indefinitely but will finally change and increase, and the long periods be on the right hand side of the graph with the short on the left. The "long inequality" in the motions of Jupiter and Saturn was a puzzle to astronomers until it was found to be due to the near commensurability of their periodic times, and the law of gravitation was upheld. It seems to me we have identically the same thing here in the case of Encke's comet and Jupiter, and we need no resisting medium or non-gravitative action of matter to produce the observed results.

PLATE 4.



Using 3.30403 years as the mean period of Encke's comet and for the periods of the planets the values given in the *American Ephemeris* and *Nautical Almanac*, we have prepared the following table:

	P. of comet / P. of planet	P. of planet / P. of comet	Nearly exact ratio	Period years	Approximate ratio	Period years
Mercury	13.718		25 E=343 My	82.6	1E=14 My	3.3
					4E=55 My	13.2
Venus	5.370		100E=437 V	330.4	8E=43 V	26.45
Earth	3.304		10E=33 Ea	33.	3E=10 Ea	9.9
Mars	1.756		25E=47 Ma	82.6	4E= 7 Ma	13.2
Jupiter		3.590	100J=359 E	1186.2	5 J=18 E	59.31
Saturn		8.915	12S=107 E	353.5	1S= 9 E	29.45
Uranus		25.428	5U=127 E	420.	2U=51 E	168.0
Neptune		49.875	10N=499 E	1648.	1N=50E	164.8

By this table we see that 100 of Jupiter's periods equal 359 of the comet's, hence 5 of Jupiter's would equal almost but not quite 18 (being 17.95) revolutions of the comet, so we find here the cause of the gradual shift of the length of the periods on the graph as above mentioned. Had the period of the comet been about 3.1 days shorter, it would have been equal exactly to 5/18 of Jupiter's period. For Mercury and Mars we see that they are back to same relation in orbits to that of the comet after 13.2 years and for Venus just twice that period must elapse. For Mercury 66 years (5x13.2) brings the phenomenon back to the same time of the year, while 79.2 agrees well with observation for near approaches of comet and Mercury, the last being December 17, 1914.

That the Earth goes through similar variations in its periodic time will be readily seen by the upper figure of Plate 4, where the variations in the length of the year are given for the period between 1890-1920. The lower line denotes 365 days 5 hours 30 minutes. The light dashed line denotes the mean length of the year, 365 days 5 hours 48 minutes 46 seconds—the average length for the 30 years shown being 6 seconds greater than this. It should be noted that the extreme variation for the Earth during this interval is 31 minutes, while that of the comet from first discovery till now is about half that number of days or 715 times as great. By the tables below it will be seen that the variations in the length of the year quite roughly repeat themselves after four years, with greater exactness after eight years, and still greater exactness after sixteen years.

Four year cycle

44	50	39	62	40	53	40	53
65	34	53	44	54	35	56	40
46	53	56	59	46	49	51	
51	50	52	56	50	53	48	

Eight year cycle

44	39	40	40
65	53	54	36
46	56	46	51
51	52	50	48
50	62	53	53
34	44	35	40
53	59	49	
50	56	53	

Sixteen year cycle.

										44	65	46	51	50	34
53	50	39	53	56	52	62	44	59	56	40	54	46	50	53	35
49	53	40	56	51	48	53	40								

The numbers represent the number of minutes that the length of the year is in excess of 365 days 5 hours. They are arranged in order in the cycle vertically in the first two and horizontally in the 16 year cycle.

The longitude of π of Encke's comet has increased 2° 36′ between 1786 and 1918 and the longitude of π of Jupiter has increased 2° 07′ during the same time. This movement of π of Encke's comet during these 132 years amounts to 70″.91 annually, but as the precession of the equinox amounts to 50″.25 we have 20″.66 as its actual displacement among the stars yearly, while that for π of Jupiter amounts to 6″.65 according to Proctor. It will be readily seen that π of Encke's comet gains 14″ annually on π of Jupiter and, as the aphelion of comet and π of Jupiter are now about 34° apart, if the same rates continue operative the aphelion of the comet's orbit will coincide with π of Jupiter's orbit in about 8300 years. And providing the above rate continues, in about 63000 years the Line of Apsides will have made a complete circuit of the heavens, so that in half that time plus 8300 years the aphelion of comet's orbit will be in the opposite part of the heavens from that of π of Jupiter's orbit.

As the π distance of Jupiter is about 4.95 A. U. and the aphelion distance of Encke's comet is about 4.10, we have something in excess of 0.85 A. U. as their nearest possible approach to each other, if comet were in same plane as Jupiter's orbit. The planes differ by an heliocentric angle of about 11°.

The longitude of Ω of the comet apparently advances about 6′ during a cycle, but since the equinox precedes about 50′ during that time the longitude of the comet's node with regards a fixed point is retrograding at rate of about 44′ during a cycle, or 44″ annually. Jupiter's Ω retrogrades nearly 16″ yearly.

During the two cycles included between 1786 and 1905 the inclination of the orbit of the comet decreased one degree. At the same rate 1500 years hence its orbit would coincide with the ecliptic, while 92 centuries ago it would have been an right angles to it. But like the earth's it probably oscillates through a limited angle.

By an inspection of the tables it will be seen that the variation in the different elements is as follows: $\Delta P = 15.40$, $\Delta a = 0.022$, $\Delta b = 0.026$, $\Delta q = 0.016$, $\Delta a = (1-e) = 0.040$, $\Delta L = 0.012$, $\Delta V = 0.0156$, $\Delta K = 0.014$, $\Delta e = 0.00489$, $\Delta \frac{1+e}{1-e} = 0.042$, $\Delta \frac{L}{a} = 0.021$, $\Delta \frac{L}{A} = 0.024$, $\Delta \frac{A}{P} = 0.045$, $\Delta \frac{a}{e} = 0.033$.

It should be noted that the ending of the years of perihelion passage can be arranged in cycles of 12 returns, the first one ending in 1789. The last figures of the years in the first cycle being of the order 2-6-9, second cycle 2-5-9, third 2-5-8, fourth 1-5-8, fifth or present cycle 1-4-8, —a figure lasting through 3 cycles, 36 returns or 118 years.

As the period is approximately 3.3 years (just a little greater than the time it takes for light to travel one parsec), 3 such periods brings it to ten years lacking a tenth, 7 such periods exceed 23 years by one tenth and 10 periods of the comet make 33 years quite closely. On examining the duration of visibility of the comet I find that the data are best arranged according to the 10 period or 33 year cycle, so I have prepared a table with date of perihelion passage arranged accordingly.

	I	II	III	IV	V
1	1786 Jan. 30	1819 Jan. 27	1852 Mar. 14	1885 Mar. 5	1918 Mar. 24
2		1822 May 23	1855 July 1	1888 June 28	
3		1825 Sept. 16	1858 Oct. 18	1891 Oct. 17	
4	1795 Dec. 21	1829 Jan. 9	1862 Feb. 6	1895 Feb 4	
5		1832 May 3	1865 May 27	1898 May 24	
6		1835 Aug. 26	1868 Sept. 14	1901 Sept. 15	
7	1805 Nov. 21	1838 Dec. 19	1871 Dec. 28	1905 Jan. 11	
8		1842 Apr. 12	1875 Apr. 13	1908 Apr. 30	
9		1845 Aug. 9	1878 July 26	1911 July 10	
10		1848 Nov. 26	1881 Nov. 15	1914 Dec. 5	

The following table, showing Duration of Visibility in days, is also arranged like the preceding one.

	Month of T	I	II	III	IV	*Sp.*	*S.*	*A.*	*W.*	Mean
1	Mar.	2	47	68	130	247				62
2	June		21	35	48		104			35
3	Oct.		56	61	71			188		63
4	Feb.	20	102	165	83				370	92
5	May		81	160	3	244				81
6	Sept.		15	51	29			95		32
7	Jan.	31	124	93	107				345	86
8	Apr.		103	111	12	226				75
9	July		10	34	55		99			33
10	Nov.		90	83	71			244		81
Totals		53	649	851	609	711	203	527	715	65.5

In the above table "Month of T" denotes month of perihelion passage on the average. *Sp* denotes spring, S = summer, A = autumn, and W = winter. It will be readily seen than when T occurs in winter or spring that the comet is observed for a much longer time than when

T comes in the summer time (the comet is generally brighter on these winter returns according to one authority). Now if we remember what was said above about the length of the period we will see that 1, 4, 7, and 10 will all come in or near the winter time if 1 does, and we note that they are separated by three returns of the comet. The total number of days that the comet has been visible is 2162 up to its reappearance on December 30, 1917. This is about 1/22 part of the interval between 1786 and 1918. By the number of days visible we mean the summation of the number of days of each return included between discovery date and date of last observation. The total visibility in days is divided up according to the different months and seasons as follows:

Jan. 132	Apr. 112	July 150	Oct. 278
Feb. 148	May 74	Aug. 300	Nov. 286
Mar. 146	June 91	Sept. 254	Dec. 191
Win. 426	Spr. 277	Sum. 704	Aut. 755

It will be seen that summer and autumn each had as many days of visibility as winter and spring combined, or over one half of the days of visibility are included in the months of August, September, October and November. It will also be seen that the above table does not agree with the preceding one, though in some way similar to it. The first table is arranged according to cycle of 10 returns of the comet—with month of perihelion passage on the average indicated so there are only 10 months indicated. The latter table is according to the number of days visible in each month and with the whole of the months indicated taken for the seasons.

A table showing the number of times that the comet had been discovered by months, the number of times that perihelion passage has taken place in each month, and the number of times that the comet was last observed in each, is here given; also the same for the seasons.

	J	F	M	A	Ma	Ju	Jy	A	S	O	N	D	Sp	Sw	A	W
Discovery	3	2	0	0	1	3	7	7	5	2	2	2	4	19	6	5
π Passage	4	2	3	3	4	1	3	2	3	2	3	4	8	8	9	9
Last Obs'd	3	0	2	1	2	3	2	4	5	2	5	4	6	11	11	5

Over one half of the discoveries have taken place during the summer months of July, August and September. Twice as many last observations take place during the last half of the year as during the first half. January, May and December are most favored with the occurrence of perihelion passage, and June the least so, the seasons being nearly the same.

We here give three tables that are self-explanatory, the plus sign denoting time after perihelion passage.

No. of days comet was discovered before or after perihelion passage						No. of days comet was last observed before or after perihelion passage				
	I	II	III	IV	V	I	II	III	V
1	13	62	72	84	86	11	15	4	+46
2		+10	+11	+10			+31	+46	+58
3		34	72	77			+22	11	6
4	44	115	141	96		24	13	+24	13
5		+19	103	+17			+100	+57	+20
6		35	72	38			20	21	9
7	33	127	101	120		2	3	18	13
8		63	76	+26			+40	+35	+38
9		36	+8	19			26	+42	+36
10		91	87	78			1	4	7

Degree of Brightness.			
I	II	III	IV
Not v. Br.			Br.
		v.f.	
f.	N.E.5	v.f.	v.f.
		v.f.	v.f.
N.E.	N.E.	f.	Q.Br.
			v.f.
		8	7 or 8
	N.E.	N.E.	7

In the degree of brightness columns v = very, Q = quite, Br = bright, f = faint, $N.E.$ = visible to naked eye, the numbers denoting apparent magnitude when brightest. Though this table is rough it shows the 1, 4, 7, 10 order quite well. Those underlined are when a tail was visible.

It would appear that the reason the comet was not observed between 1786 and 1819, except in 1795 and 1805, was that it was very faint, the times when it was observed being on the 1, 4, 7 order. In the discovery and last observed columns will be noted several close agreements as to number of days before or after perihelion passage that the comet was discovered or last observed, when referred to the cycle order; and especially to be noted is the large number of days in the 1, 4, 7, 10 order of the time of discovery, and 2, 5, 8 order last observed.

The lower graph on Plate 4 is to illustrate the variation in visibility of the comet. The ordinates denote days, with 0 as time of perihelion passage. Those below 0 denote days before, while those above 0 denote days after perihelion passage. The light lines denote times of discovery of the comet in days before or after perihelion passage, while the heavy lines represent the times in days before or after perihelion passage when last observed. The solid continuous line represents the visibility cycle of 1815-1848, the short dash line the cycle 1848-1881, and the long dash dot line the cycle 1881-1914. The observations of 1786, 1795, 1805 and 1917 are shown by dots, the heavier being for last observation.

The central shaded figure (Plate 4) represents the average time of discovery and last observed in days before or after perihelion passage. We note that 1, 4, 7, 10 are long on the discovery side and 2, 5, 8 are long on the last observed side. In each case the difference is three returns or 9.9 years which brings the comet back into a good place for observation, 4 being the most favorable for discovery and 5 for last observation.

The left hand part of Plate 5 shows the position that the comet occupied at times of discovery and when last observed at different returns. The month of discovery or last observation, year, and number of days before or after perihelion passage are shown thereon. The plus sign

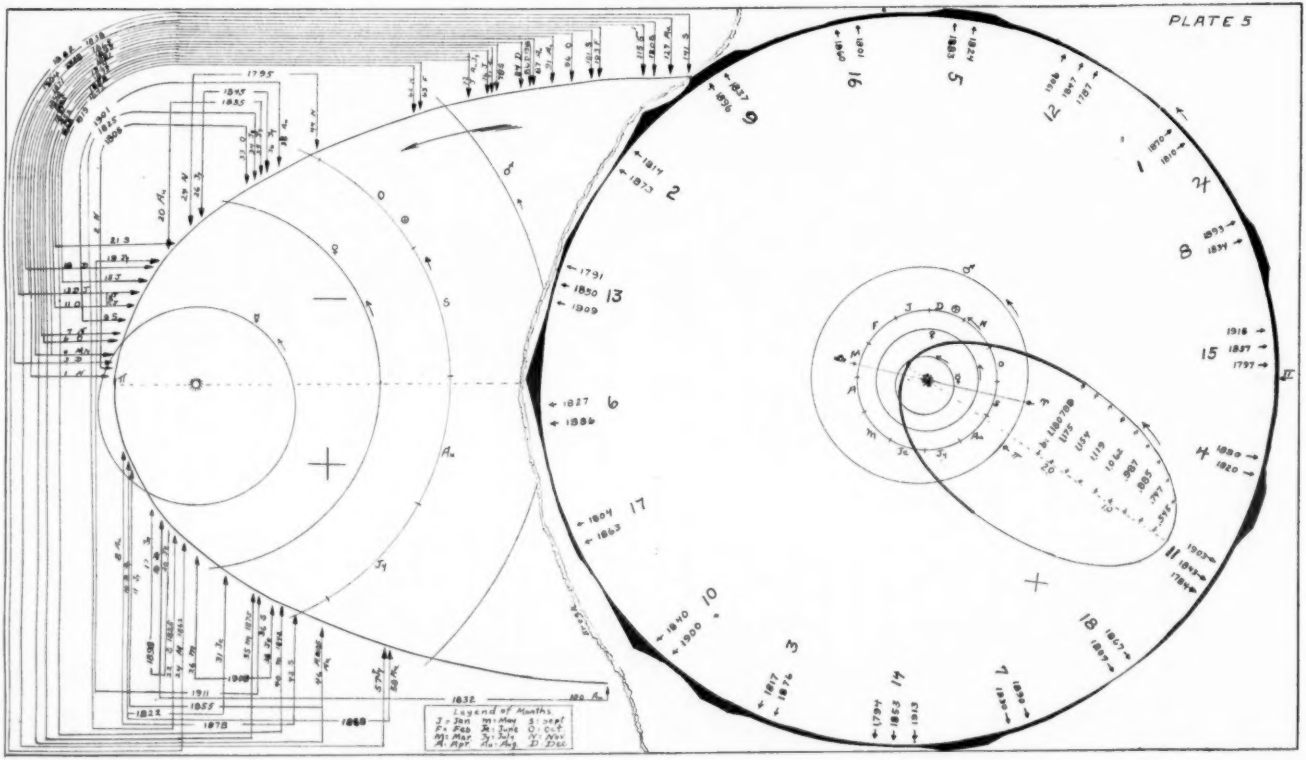


PLATE 5
Legend of Months
J: Jan M: May S: Sept
F: Feb Jn: June O: Oct
M: Mar Jl: July N: Nov
A: Apr Au: Aug D: Dec

denotes after perihelion passage. It will be seen that it has been discovered 18 times (or over one half) when at a distance greater than that of the earth from the sun, and last observed on only five times when comet's distance was outside earth's orbit.

The right hand part of Plate 5 shows the orbits of the planets Mercury, Venus, Earth, Mars, Jupiter and the comet. The part of the orbit where the comet has been observed is shown by a heavy line, the unobserved part by a light line. Jupiter's orbit is shown by a line of varying width. The numbers 1, 2, etc. and the years, just inside Jupiter's orbit, are those given in Table III, being the numbers in the element cycle, and denote the position of Jupiter at that time. Thus it will be seen that Jupiter in 1870, after a complete cycle, was back to almost the same position that it had in 1810. It will also be seen that when the comet's period was the longest Jupiter was very close to the aphelion of the comet's orbit, as in 1784, 1843, and 1903. The variation in the width of the line representing Jupiter's orbit shows the variation in the length of the comet's period with regard to Jupiter's position with reference to his perihelion at time of aphelion passage of the comet. It will be seen that these variations are approximately symmetrical with Jupiter's line of apsides, and is but another way of illustrating *P* of Plate 3.

The ordinates of the ellipse, Plate 5, were calculated by the formula

$$y = \sqrt{(1-e^2)(a^2-x^2)}$$

and are expressed in the astronomical unit, and are for every 1/4 A.U. from the extremity of the major axis of the ellipse to its center, except the center one or *b* which is at a distance of the semi-major axis. These values are for an approximately mean orbit.

In 1861 the comet was discovered 141 days before it passed perihelion and in 1832 it was last observed 100 days after having passed perihelion. These being the extreme observations, we have the following table:

Days	*r*	*M*	*u*	*v*
		°	° ′	° ′
141	2.194	42.06	90 42	148 29
100	1.796	29.76	76 55	139 55
241			167 37	288 24

where *r* is the distance that the comet is from the sun, *M* the mean anomaly, *u* the eccentric anomaly and *v* the true anomaly of the comet. It will be seen that the maximum distance that the comet has been seen from the sun is a little less than the semi-major axis of its orbit. Now the comet in 241 days (or 1/5 of its period) describes an heliocentric angle of about 288°.4 (or 4/5 of a circle) when in that part of the orbit near the sun, but to describe the remaining 71°.6 (or 1/5 of a

circle) requires 961 days (or 4/5 of its period). In the 1/5 of its period it has described nearly one half the perimeter of the orbit. As will be seen from the value of u the comet will traverse the half of its orbit next to the sun in about 280 days or 7/30 of the period.

The upper figure of Plate 3 is platted with the periods of the comet as ordinates and the eccentricity of the orbit as abscissas and a straight line is drawn through them from 1211 days with $e=0.8445$ to 1200 days with $e=0.8494$. Over 1/3 of the periods are within 1/2 day of this line, over 1/2 fall within one day of it, while almost 3/4 are within 1½ days and over 4/5 are within 2 days of the line. From the close agreement of most of the values of P with the line, we may say that as P increases e decreases proportionately, an increase of one day in P amounting to a decrease in e, according to the line value, of 0.0004454.

Much has been written about this comet, especially in the acceleration line, but I think that all the matter here presented is entirely new, as I have run across nothing similar in a search for data on this comet covering many months of time and consulting many works and authorities.

In the past the study of comets as regards their orbits has been considered almost entirely from long mathematical calculations of the perturbations and the elements of the orbit; all well and good and necessary, but with cycle study of the elements of an orbit we have opened up to us a new method of obtaining approximate results, and also perhaps of indicating large errors, and worthy to be tried. While we do not wish to claim the impossible for it, yet we believe that in time it will be recognized as important and fundamental to know the cycles of the best known periodic comets as the cycles that pertain to the moon. I realize that this is not the past nor the present idea of most astronomers. Moseley said in his "Lectures on Astronomy" (3rd ed. rev. London 1850, p. 201-202): "it appears that those changes which, in respect to the orbits of the planets are necessarily, and must ever be, *gradual* and almost imperceptible, are, as it regards the orbits of the comets, not only perceptible, but remarkable, and moreover that, whereas the changes of the planetary orbits must return in certain cyclical periods forever, those of the comet orbits will not; so that what the cometary system is at any given time, it can never (that is, it cannot except by an infinite improbability) be again; but to what this perpetual series of changes tends, or in what it will terminate, no one has, probably, been bold enough to make the subject of his speculations." Professor H. N. Russell in a personal letter says: "In general I would advise extreme caution in the prediction of any cycle in the motion of a periodic comet, and most of all in that of Encke's comet, which is known to be subject to retardation by some non-gravitational

force. The motion of a comet is an exceedingly complicated thing from the mathematical standpoint and it is probable almost to the point of certainty that any apparent cycle holding good for ten or twenty returns is in reality only the integrated effect of a great number of periodic terms (if indeed the motion is expressible by periodic terms at all) and that the cycle will fail when applied to prediction over any considerable range. This happened to Augsleow's cycle for Halley's comet." These two well present the other side of the cycle problem (in fact all that I found relating thereto). I will say in conclusion that I have shown that the motion of Encke's comet is cyclic through at least 34 returns, and that the comet's motions are as regular as that of a planet though greater in magnitude. To those mathematically inclined I will say—investigate.

Alma Center, Wis.

A GRAPHICAL SOLUTION OF THE ASTRONOMICAL TRIANGLE.

W. CARL RUFUS.

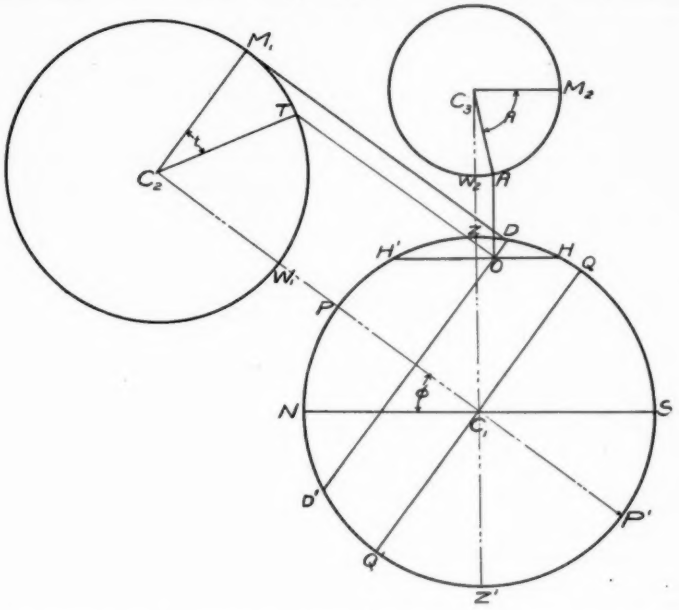
The transformation of celestial coördinates from the horizon system to the equator system, or vice versa, and other problems involving the solution of the astronomical triangle*, form an important part of the work of elementary practical astronomy. The simple relationship between the two systems of coördinates and the parts of the triangle frequently appears hopelessly complicated to the beginner, and the application of the appropriate formulae of spherical trigonometry adapted to logarithmic computation sometimes adds to his bewilderment.

The following graphical solution provides a simple method of approach to the problem, and gives an approximate result generally within 30′ with ordinary care and skill. In addition to ordinary drawing instruments, parallel rulers† are necessary for the last case.

* The triangle formed on the celestial sphere by the observer's meridian, the star's hour circle and vertical circle, i. e. the triangle whose vertices are the pole, zenith and star.

† The Solution of Spherical Triangles for the Mathematical Laboratory, Herbert Bell, p. 51.

The accompanying figure was drawn by Mr. Carl T. Hogan, a student of civil engineering in the University of Michigan, who obtained excellent results in the solution of typical problems by the graphical method.



The largest circle, center C_1 represents the celestial sphere orthogonally projected on the plane of the observer's meridian. To visualize the underlying conception, a celestial globe or armillary sphere may be adjusted to represent the conditions of the problem. Then receding towards the west, let the observer imagine himself in the plane of the horizon of the globe looking back from an infinite distance. The horizon circle, equator, declination and altitude circles, will then appear as straight lines traced on the plane of the meridian.

N S = the horizon; N, north, S, south.
Q Q′ = the equator.
P P′ = the axis of rotation: P, north pole; P′, south pole.
Z Z′ = the plumb line: Z, zenith, Z′, nadir.
O = star or object.
arc S H = h, altitude of star.
H H′ = altitude circle, parallel with horizon.
arc Q D = δ, declination of star.
D D′ = declination circle, parallel with equator.
arc Q Z (declination of zenith) = arc N P (altitude of pole) = ϕ, geographical latitude of observer.

The second circle represents the star's declination circle as seen from an infinite distance beyond P, the north pole. Its center C_2 lies on the axis produced, and its diameter equals D D′. The relation to the primitive circle may be seen by imagining its plane turned through an angle of 90° on a diameter parallel with D D′.

M_1 = projection of D, south intersection with the meridian.
W_1 = west point.
arc M_1 T = t, hour angle of the star.

Similarly the third circle represents the star's altitude circle as seen from an infinite distance above Z, the zenith, with center C_3 on the plumb line produced and diameter equal to H H′. It is also turned through an angle of 90° from its position in circle 1.

M_2 = projection of H, south intersection with the meridian.
W_2 = west point.
arc M_2 A = A, azimuth of the star.

We shall consider only the most frequent cases arising in elementary practical astronomy.

Case 1. Transformation of Coördinates.

(a) Given, latitude ϕ, declination δ and hour angle t, to find altitude h, and azimuth A.

Construct the primitive circle with center C_1 and horizon N S, laying off arc N P = ϕ to define the axis P P′ and drawing the plumb line ZZ′ and the equator QQ′ perpendicular respectively to N S and PP′.

Lay off arc QD = δ and draw DD′, the trace of the declination circle, parallel with the equator.

Construct the declination circle with Center C_2 on the axis produced and radius equal to one-half D D′.

Draw D M_1 parallel with the axis; M_1, being the point of tangency with circle 2, and representing the point of intersection with the meridian. Lay off arc M_1 T = t, the hour angle of the star.

Draw T O parallel with the axis: O the point of intersection with D D′ gives the position of the star projected on the primitive circle.

Through O parallel with the horizon draw H H′, the trace of the altitude circle. Then the arc S H gives the measure of the star's altitude h.

To find the azimuth draw the altitude circle with center C_3 on the plumb line produced and diameter equal to H H′. Locate M_2 and A, projections of H and O respectively. The arc M_2A = A, the azimuth.

(b) Given latitude ϕ, altitude h and azimuth A, to find declination δ and hour angle t.

The preceding construction may be followed, reversing the order of the use of circles 2 and 3 and related coördinates.

CASE 2. Given latitude ϕ, declination δ, and altitude h, and knowing whether the star is east or west of the meridian, to find hour angle t, and azimuth A.

Construct circle 1. Lay off arc Q D $= \delta$ and draw D D′ parallel with the equator. Similarly arc S H $= h$ and H H′ parallel with the horizon. The intersection of D D′ and H H′ determines O.

Draw the declination and altitude circles and the projection of O will determine t and A respectively, due attention being paid to the quadrant.

CASE 3. Given declination δ, hour angle t and altitude h, to find the latitude ϕ. Azimuth A may also be obtained.

Construct circle one, drawing Q Q′ arbitrarily, and P P′ perpendicular to Q Q′ through C_1. Lay off Q D $= \delta$ and draw D D′.

The declination circle may now be constructed and with arc M_1 T $= t$ the point T is determined. The projection of T on D D′ gives the point O.

Parallel rulers may now be used to determine ϕ. With one edge at C_1 and the other at O, rotate the parallel rulers until they cut off an arc on the circumference of circle 1 equal to the given altitude h. The edges of the rulers on C_1 and O will determine the trace of horizon SN, and of the altitude circle H H′. The arc N P measures the latitude ϕ.

The altitude circle C_3 may be drawn; the projection of O will give A. Then the arc M_2A measures the azimuth.

VISUAL ESTIMATES OF THE BRIGHTNESS OF NOVA AQUILAE, No. 3.

JOEL STEBBINS.

The outburst of Nova Aquilae has again shown the value of coöperation among observers, as it is quite impossible for a single person to follow the rapid changes of an object like this. Even when the sky is clear for many nights in succession, the variations at the beginning of the outburst may cause a complete transformation between one night and the next. The only way then to follow the changes is for many observers to determine the light of the Nova with such means as they possess. Fortunately, the errors of simple estimates by Argelander's method of "grades" are small when compared with the light changes of the star.

The writer learned of the Nova on the day after the eclipse of June 8, 1918, while at Rock Springs, Wyoming, and it was that same night that the star reached its maximum. There seems to be an uncertainty as to just how bright the Nova really became, but naturally those of us who saw it are pretty sure of our impressions. I watched the star carefully from dusk on June 9 until about two hours after sunset, $16^h\ 40^m$ G.M.T., and was quite sure that the Nova was fainter than Sirius. This was also the estimate of my colleague, Mr. Kunz. By this we mean of course that the new star rising in the east was not as bright as Sirius would be at the same altitude. We should have liked to say that the Nova was the brightest fixed star in the sky, but in this we were disappointed. The sky was clear, and there were no clouds or smoke to interfere.

If others made different estimates of the Nova, the only thing to do is to take an impartial judgment on the evidence. The comparison with Sirius was not as definite as though both stars had been visible together, but the estimate is of some value, and the next time I saw Sirius I was positive that the Nova had not been that bright. My comparison with Vega and Altair made the Nova of about magnitude -0.8 at $16^h\ 40^m$ G.M.T., June 9, and this would indicate that the star was only about half as bright as Sirius.

It seems to me too much in the way of charity, or sarcasm, to pass over as of wrong date such reported observations as those which state that the Nova was seen as a first magnitude star on June 6 and 7. There are no doubt people in the world who, on hearing of such an interesting phenomenon as the appearance of a Nova, will remember having seen a bright star somewhere the week before, and on thinking it over will perhaps convince themselves that they really saw the Nova on such and such a date. Then there are others who will simply manufacture observations in cold blood. Therefore when some belated absurd announcement concerning the discovery or brightness of the Nova is made, it is for the observer himself to furnish the explanation of his aberrations.

The observations which follow have been made by the method of grades in the usual way. The value of one grade has been taken to be 0.10 magnitude. On the first few nights, however, the difference between the light of the stars was so great that the number of grades was uncertain, and where the fraction ½ appears it indicates that the estimate was made not in grades but in fractions of an interval, e. g. Nova ½ Vega 1 Altair means that Nova was brighter than Vega by an amount one-half as great as the difference between Vega and Altair.

The comparison stars, with their adopted magnitudes from *Harvard Annals*, Vol. **50**, are:

TABLE I.

COMPARISON STARS.

Designation	Star	Magnitude
—	Vega	0.14
—	Altair	0.89
α	α Ophiuchi	2.14
γ	γ Aquilae	2.80
η	η Serpentis	3.42
δ	δ Aquilae	3.51
θ	θ Serpentis	4.10
β	β Scuti	4.47
z	4 Aquilae	5.04
w	5 Aquilae	5.68

Except where noted, the observations were all made with the naked eye. The places of observation with the the corresponding dates were:

June 9, 10	Rock Springs, Wyo.
June 11	Omaha, Nebr.
June 14	Lincoln, Nebr.
June 15, 17, 18	Omaha, Nebr.
June 22, 25	Urbana, Ill.
July 2 to Aug. 16	Langley Field near Hampton, Va.
Aug. 19	Cambridge, Mass.
Aug. 30 to Sept. 9	Langley Field.
Sept. 10	Steamer in Chesapeake Bay.
Sept. 24 to Dec. 10	Urbana, Ill.

TABLE II.

Magnitude Estimates of Nova Aquilae No. 3.

1918		G.M.T. h m	Comparison	Magnitude	Remarks
June	9	15 40	N = Vega	−0.7	
	9	16 00	N > Vega	...	Still too low for comparison.
	9	16 40	N ½ Vega 1 Altair	−0.8	
	10	16 00	... ...	...	Nova apparently no brighter.
	11	15 45	Vega ½ N ½ Altair	+0.5	
	14	15 30	Altair 5 N	1.6	N is reddish
	15	15 40	Altair ½ N ½ α	1.5	N fainter than last night
	17	15 20	N 3 α	1.5	
	18	15 15	α 1 N	1.9	
	22	19 00	γ 2 N	3.0	
	25	16 35	N 2 η	3.2	
July	2	13 45	N 3 η	3.1	
	3	14 15	N 4 η	3.0	
	4	14 35	N 5 η	2.9	
	8	19 —	δ = N = η	3.5	
	9	14 —	δ 3 N, η 2 N	3.7	
	10	13 45	η 4 N 3 θ	3.8	
	12	14 —	η 4 N 3 θ	3.8	
	15	14 45	η 4 N 4 θ	3.8	
	16	13 45	η 4 N 4 θ	3.8	
	20	14 05	N 3 θ	3.8	Binoculars, moon.
	26	14 05	η 5 N 3 θ	3.8	
Aug.	3	15 20	θ 4 N 6 z, β 2 N	4.6	Haze.
	4	14 00	θ 3 N, β 2 N	4.5	
	8	13 30	η 5 N 3 θ	3.8	N is brighter.
	13	13 30	θ 4 N = β	4.5	
	15	14 40	θ 5 N 3 z	4.7	
	16	13 40	θ 5 N 4 z	4.6	Moon.
	19	14 —	θ 3 N	4.4	Moon.
	30	15 00	θ 7 N 5 z	4.6	
Sept.	1	13 30	β 5 N 3 z	4.8	
	2	14 00	β 5 N 3 z	4.8	
	3	14 45	β 5 N 3 z	4.8	
	4	13 30	β 4 N 4 z	4.8	
	9	14 15	θ 6 N 3 z	4.7	
	10	13 10	N 2 z	4.8	
	24	13 00	N 2 z	4.8	Binoculars on this and all subsequent dates.
	26	13 00	N = z	5.0	
	27	14 30	N = z	5.0	
	29	13 30	N 1 z	4.9	
Oct.	3	12 45	N = z	5.0	
	5	13 00	N 3 z	4.7	
	6	12 50	N = z	5.0	
	27	12 10	z 5 N 3 w	5.4	
	28	12 15	z 5 N 3 w	5.4	
	29	11 55	z 5 N 4 w	5.4	
Nov.	1	13 30	z 4 N 6 w	5.3	
	4	13 30	z 3 N 6 w	5.3	
	5	12 20	z 5 N 4 w	5.4	
	10	12 05	z 5 N 5 w	5.4	
	11	11 40	z 5 N 4 w	5.4	
	12	11 35	z 5 N 4 w	5.4	
	24	11 40	z 4 N 4 w	5.4	
	25	12 00	z 4 N 4 w	5.4	
	29	11 30	z 4 N 4 w	5.4	
Dec.	10	12 05	z 5 N 4 w	5.4	

The adopted magnitudes in Table II are readily derived from the magnitudes of the comparison stars. All cases where the correction for atmospheric absorption has been applied are given in Table III where the details of the computation are shown.

TABLE III.

CORRECTIONS FOR EXTINCTION.

Date, Sid. Time	June 9, 13h 34m		June 9, 14h 34m			June 11, 14h 40m		
Comparison	Nova = Vega		Nova ½	Vega 1	Altair	Vega ½	Nova ½	Altair
Zenith distance	80°.4	56°	69°	45°	75°	44°	68°	74°
Corrected magnitude	−0.70	0.14	−0.85	0.14	0.89	0.14	0.47	0.89
Extinction	1.02	0.18	0.42	0.09	0.65	0.08	0.39	0.60
Apparent magnitude	0.32	0.32	−0.43	0.23	1.54	0.22	0.86	1.49
Difference	0.00		0.66	1.31		0.64	0.63	

Date, Sid. Time	June 14, 14h 34m		June 15, 14h 51m			June 17, 14h 38m		June 18, 14h 37m	
Comparison	Altair 5	Nova	Altair ½	Nova ½	α Oph.	Nova 3	α Oph.	α Oph. 1	Nova
Zenith distance	75°	69°	72°	66°	45°	69°	47°	47°	69°
Corrected Magnitude	0.89	1.62	0.89	1.48	2.14	1.52	2.14	2.14	1.92
Extinction	0.65	0.42	0.52	0.34	0.09	0.42	0.10	0.10	0.42
Apparent magnitude	1.54	2.04	1.41	1.82	2.23	1.94	2.24	2.24	2.34
Difference	0.50		0.41	0.41		0.30		0.10	

For illustration, the second computation for June 9 will be explained. At 14h 34m local sidereal time at Rock Springs the Nova was compared with Vega and Altair. The computed zenith distances of the three stars were respectively 69°, 45°, and 75°, which from Müller's table give extinctions of 0.42, 0.09, and 0.65 magnitude. Applying these corrections to Vega and Altair we have 0.23 and 1.54 as the apparent magnitudes of the comparion stars, and the difference of magnitude is 1.31. One half of this difference is 0.66 which is the amount that Nova was brighter than Vega; or Nova had an apparent magnitude of −0.43, which with the extinction of 0.42 gives the corrected magnitude as −0.85. In short, the computations in the table are made downward for the comparison stars and upward for the Nova.

My estimate of the transparency of the sky on June 9, which was first class, was that the extinction would be well represented by Müller's table. At Urbana, where photo-electric measures are made in blue light, we use an extinction correction which varies from 1.5 times the tabular value on the best nights, to three or four times that amount when the sky is hazy; but after considerable experience I think that the tabular values are about right for visual observations with a good sky. Any table, however, is only a guide, for it sometimes happens that the extinction will change over the whole sky in only a few minutes, and without clouds forming. On clear nights at Urbana the transparency often becomes progressively better until shortly before dawn, when there seems to be a tendency for the sky to become hazy.

Sometimes Nova was estimated visually on the same night that I measured the star with the photo-electric photometer. The estimate

was then always made before beginning the other work, so as to avoid any prejudice. As a few readings with the photometer give a result which is far superior to anything I can possibly secure visually, it was interesting to note how variations of a few tenths of a magnitude were followed easily with the instrument, but were missed altogether by the eye. On the other hand, visual changes were not always confirmed by the photometer. The estimate of October 5 made the Nova three grades brighter than it had been on several nights preceding, but the instrument showed that the star was actually about 0.02 magnitude fainter than before. In fact, when the photo-electric measures could be secured there was little use of my making estimates. The photo-electric work, which has been carried on by Dr. Elmer Dershem and myself, will be published in another article.

University of Illinois Observatory.

1919, January.

A SUGGESTION AS TO SATELLITE EVOLUTION.

WILLIAM H. PICKERING.

The course of evolution of a satellite need not necessarily be, and probably is not, identical with that of a planet. We know approximately the masses of each of the four larger satellites of Jupiter, and we know also their dimensions. These facts furnish us with a knowledge of their densities, which according to H. A. **61**, 75, assuming Damoiseau's masses, range from 1.00 to 2.11, and assuming those of Adams, from 0.68 to 1.94, water being taken as 1.00. The albedo of the fourth satellite is 0.10, and for the three inner ones it ranges from 0.22 to 0.32. The albedo of our moon is 0.09, of Jupiter 0.62. The three inner satellites are therefore composed of white material, which however is not as bright as a cloud. As planetary objects they are of too small mass in any case to retain cloudy atmospheres. The difference between their bright sharp limbs and the dark indistinct limb of Jupiter is very striking under favorable definition. Since we know of no solids of such small density, it is clear that they must be dense meteor swarms or dust clouds, perhaps mixed with snow, their varying ellipsoidal shapes being maintained by their own gravity.

The rings of Saturn we know are also of meteoric constitution, and they too are very white, although of unequal brilliancy. We can hardly doubt that Saturn's inner satellites therefore are also meteoric, although Iapetus on account of its changing brightness appears to be solid. This does not necessarily follow however, since it might be egg-shaped, performing half a rotation about a minor axis in one orbital revolution.

Saturn's rings can never condense to form satellites on account of their proximity to the planet, which brings them within Roche's limit, but we can hardly doubt that all of its other satellites, as well as those of Jupiter, were once meteoric rings, even if formerly nearly as scattered and transparent as the solar ring of asteroids. The difficulty with this hypothesis hitherto has been, in case their structure was fairly uniform, to account for their destruction, and condensation into one spherical mass.

In Figure 1 let AB represent a planet and a ring of meteoric satellites revolving in the plane of the planet's orbit. Owing to the attraction of the Sun, the satellites will continue to move faster and faster from A

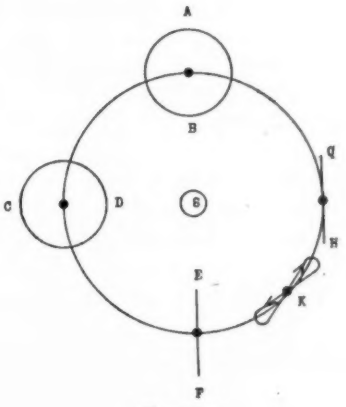


FIGURE 1.

to B, after which their speed will gradually diminish until they again reach A. The same thing will happen when the planet reaches CD. The ring will change its shape slightly in accordance with the change of position, and the satellites will be closer together after passing B or D than before, when they were on the other side of their orbits, but there will be no tendency for the ring to break up.

Suppose now that by polar inversion the planet and its ring are revolving about an axis lying in the plane of the planet's orbit, as

shown at EF. Precisely the same state of affairs will occur, and the satellites in the ring will be moving fastest at E, and slowest at F. This will continue until the planet arrives at GH. But here there is no excess of velocity due to solar pull on the satellites, and instead of the condensation slowly moving around the ring, it simply gradually becomes less and less on one side of it, and then more and more on the diametrically opposite side. This will occur twice every revolution. At GH the ring will also be thrown slightly outside of the planet's orbit. At any intermediate position K, the ring will assume a twisted shape when seen edgewise, like a figure 8. The matter is too recondite to admit of simple mathematical proof, but it would seem that a gradual alternate condensation and rarefaction of the meteors occurring on one side of the ring would be more likely to result in collisions than would a uniform condensation which slowly travelled around it. The continuous writhing and twisting of the ring, however, might be even more effective in producing this result.

The only satellite in our solar system whose primary has not submitted to polar inversion is that of the planet Neptune, but even here the inclination of its orbit to the ecliptic is at present as much as 35°, which, taken in connection with the long time that the satellite has had in which to condense, may well account for the break up of the original ring. According to Stratton (M. N. 1906, **66**, 400) it is probable, owing to polar inversion, that this inclination was formerly still greater.

Mandeville, Jamaica, B. W. I.
Nov. 21, 1918.

REMARKABLE HAIL-STORMS.

WILLIAM H. PICKERING.

A remarkable fall of hailstones occurred at Provins and at Everly in France on July 29, 1917. It is said to have been the most severe in over fifty years. The velocity of the wind was estimated at 80 miles an hour, and half an hour after the fall ceased the ground was still covered with hail, some four inches in depth, in places. The fall lasted for about twenty minutes. Many of the hailstones were as large as hen's eggs, and some measured over two inches in diameter. One was said to have weighed 160 grams, or about one third of a pound. Natur-

ally much damage was done, but oddly enough no one was injured. Some dead game was found in the fields, however, whether birds or rabbits is not specified, but evidently no larger animals were hurt (L'Astronomie, 1918, **32**, 324).

A wind velocity of 80 miles per hour would be equivalent to 117 feet per second. If the hailstones fell vertically with this same velocity, this would give them a total speed of 165 feet, or about twice that of a swift and icy snowball. The record speed for throwing is about 130 feet per second. This is based on the throw of a Lacrosse ball in 1902 at Ottawa, through a distance of 497 feet 7.5 inches.

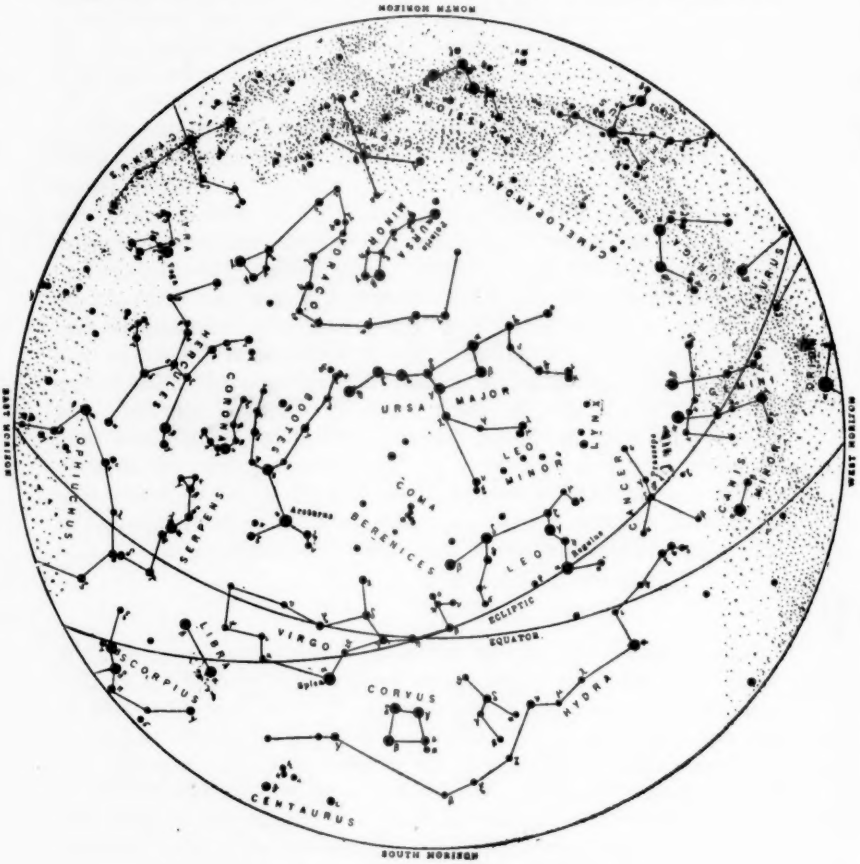
Three other accounts of violent hailstones are related by Darwin, in "The Voyage of the Beagle" p. 113. The first occurred in Patagonia, and is by the Jesuit Drobrizhoffer, who declares that on one occasion vast numbers of cattle were killed by hail. The second is by a Dr. Malcomson, who states that in 1831 he witnessed in India a hailstorm which killed large birds and injured cattle. These hailstones were disk-shaped, one measuring three-inches in diameter. Another one weighed two ounces. Its bulk was therefore 4 cubic inches. The third account is by Darwin himself, who at that time was twenty four years of age, and relates again to Patagonia. On arriving at a new camp, he says that the Indians told him that on the previous night hailstones had fallen of the size of small apples; that the hail had killed twenty deer, of which he saw the fresh hides. Numbers of ostriches and smaller birds were also killed. He saw some of them, and dined off of one of the ostriches. He evidently believed the story, but it is certainly a little singular that in none of these four cases was it stated that either man, woman, or child was killed, or even severely injured. It would be of interest to learn if such a case has ever occurred.

Mandeville, Jamaica, B. W. I.
December 26, 1918.

NOTE. Since the above was written a reference has appeared in the Journal of the Royal Astronomical Society of Canada, 1918, **12**, 532, Plate 22, to a violent hail storm that occurred on August 7, 1918, at Brittania near Ottawa. The note is by A. Steadworthy, of the Dominion Astronomical Observatory. The velocity of the wind was 50 to 60 miles an hour, and one of the hailstones measured $2\frac{3}{4} \times 2 \times 1\frac{1}{4}$ inches. In all of these accounts the dimensions of the stones are about the same, and we may judge that they probably represent approximately the maximum limit of size.

PLANET NOTES FOR MAY, 1919.

The *Sun* will move in a northeasterly direction from the constellations Aries into the constellation Taurus during this month. It will pass the Pleiades and at the end of the month will be a short distance north of Aldebaran. At the beginning of the month its position will be R. A. $2^h\ 31^m$ declination $+\ 14°\ 50'$ and at the end of the month, R. A. $4^h\ 29^m$ declination $+\ 21°\ 48'$. The sun will be approaching its greatest northerly declination for the year, and places in northern latitudes will



THE CONSTELLATIONS AT 9:00 P. M. MAY 1.

be approaching the longest day.

On May 28 there will be a total eclipse of the sun. This eclipse will be invisible at Washington. For a further description and diagram of the path of this eclipse, see the January, 1919, issue of POPULAR ASTRONOMY.

The phases of the *moon* for this month are as follows.

First Quarter	May	6	at	6	P.M. C.S.T.
Full Moon		14	"	7	" "
Last Quarter		22	"	3	" "
New Moon		29	"	7	A.M. "

The *moon* will be nearest the earth on May 28 and farthest from the earth on May 13.

Mercury on May 5 will reach a position of greatest elongation west. At this time Mercury will be several degrees south of the sun and will not be easy to observe. It will be visible in the morning sky just before sunrise.

Venus will be the brilliant evening star during this month. It will be moving eastward more rapidly than the sun and will consequently be higher in the sky from day to day at sunset. At the middle of the month it will cross the meridian at 2:45 p. m. Venus will be approaching the earth throughout the month and at the close of the month will be at a distance from the earth equal to the mean distance of the sun.

Mars will be in conjunction with the sun on May 9. It will therefore not be visible at all.

Jupiter will still be a few hours east of the sun and consequently will be seen as a brilliant object in the west at sunset. The sun, however, will be overtaking Jupiter. By the end of the month, Jupiter will cross the meridian at 2:40 p. m.

Saturn will continue to be in a most favorable position for observation during this month. It will be in quadrature six hours east of the sun on May 13.

Uranus will be a few hours west of the sun. Because of its southern declination it will be rather difficult to observe, as it will not rise very long before the sun.

Neptune, having passed quadrature in April, will be west of the meridian at sunset. It will, however, be in a position to be observed throughout the month.

Phenomena of Jupiter's Satellites.

VISIBLE AT WASHINGTON.

[From the *American Ephemeris.*]

CENTRAL STANDARD TIME.

1919	h	m		
May 1	7	16	I	Ec. R.
2	6	31	II	Tr. I.
	8	18	IV	Tr. I.
	8	47	II	Sh. I.
	9	15	II	Tr. E.
7	8	32	I	Tr. I.
	9	35	I	Sh. I.
8	6	37	III	Ec. D.
	9	12	I	Ec. R.
9	9	17	II	Tr. I.
11	7	03	IV	Ec. R.

1919	h	m		
May 11	8	22	II	Ec. R.
15	7	50	I	Oc. D.
16	7	16	I	Tr. E.
	8	14	I	Sh. I.
19	7	09	IV	Tr. I.
23	7	01	I	Tr. I.
	7	53	I	Sh. I.
24	7	31	I	Ec. R.
26	8	10	III	Sh. E.
27	7	00	II	Tr. E.
	8	43	II	Sh. E.

Note:—I., denotes ingress; E., egress; D., disappearance; R., reappearance; Ec., eclipse; Oc., occultation; Tr., transit of the satellite; Sh., transit of the shadow.

Occultations Visible at Washington.

[From the *American Ephemeris.*]

Date 1919	Star's Name	Magnitude	IMMERSION. Washington M.T. h m	IMMERSION. Angle from N. °	EMERSION. Washington M.T. h m	EMERSION. Angle from N. °	Duration h m
May 4	162 B Gemin.	5.7	11 00	109	11 51	284	0 51
8	237 B Leonis	6.3	10 59	52	11 29	2	0 30
14	147 B Librae	6.2	8 25	152	9 20	246	0 55
14	172 B Librae	5.9	13 31	99	14 59	274	1 28
17	14 Sagittarii	5.6	13 29	89	15 01	255	1 32
18	195 B Sagittarii	6.3	15 54	102	17 08	220	1 14
26	19 Arietis	5.8	15 44	66	16 37	254	0 53

Saturn's Satellites.

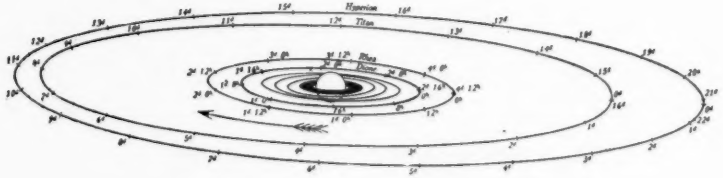
[From the *American Ephemeris.*]

CENTRAL STANDARD TIME.

I. Mimas. Period 0^d $22^h.6$.

1919	h		h		h		h
May 2	14.6 E	May 11	13.5 W	May 20	12.5 E	May 29	11.4 W
3	13.2 E	12	12.2 W	21	11.1 E	30	10.0 W
4	11.9 E	13	10.8 W	22	9.7 E	31	8.6 W
5	10.5 E	14	9.4 W	23	8.3 E		
6	9.1 E	15	8.0 W	24	6.9 E		
7	7.7 E	19	13.8 E	28	12.8 W		

South



North

SATELLITES OF SATURN, 1919

Apparent Orbits of the Seven Inner Satellites of Saturn at Date of Opposition, February 14, 1919, as seen in an inverting telescope.

II. Enceladus. Period 1^d $8^h.9$.

May 1	17.1 E	May 9	22.5 E	May 18	3.8 E	May 25	0.3 E
3	2.0 E	11	7.3 E	19	12.7 E	26	9.2 E
4	10.9 E	12	16.2 E	20	21.6 E	27	18.1 E
5	19.8 E	14	1.1 E	22	6.5 E	29	3.0 E
7	4.7 E	15	10.0 E	23	15.4 E	30	11.9 E
8	13.6 E	16	18.9 E				

III. Tethys. Period 1^d $21^h.3$.

May 2	10.8 E	May 10	0.0 E	May 17	13.3 E	May 25	2.6 E
4	8.1 E	11	21.3 E	19	10.6 E	26	23.9 E
6	5.4 E	13	18.7 E	21	8.0 E	28	21.2 E
8	2.7 E	15	16.0 E	23	5.3 E	30	18.6 E

IV. Dione. Period $2^d\ 17^h.7$.

		h			h			h			h
May	2	8.9 E	May	10	14.0 E	May	18	19.2 E	May	27	0.3 E
	5	2.6 E		13	7.7 E		21	12.9 E		29	18.0 E
	7	20.3 E		16	1.4 E		24	6.6 E			

V. Rhea. Period $4^d\ 12^h.5$.

May	3	7.9 E	May	12	8.8 E	May	21	9.8 E	May	30	10.8 E
	7	20.4 E		16	21.3 E		25	22.3 E			

VI. Titan. Period $15^d\ 23^h.3$.

May	3	2.7 E	May	10	20.4 W	May	19	1.9 E	May	26	19.8 W

VII. Hyperion. Period $21^d\ 7^h.6$.

May	7	13.6 E	May	18	6.5 W	May	28	23.0 E			

VIII. Iapetus. Period $79^d\ 22^h.1$.

						May	17	6.3 S			

IX. Phoebe. Period $523^d\ 15^h.6$.

		α Ph.$-\alpha$ Sat.	δ Ph.$-\delta$ Sat.			α Ph.$-\alpha$ Sat.	δ Ph.$-\delta$ Sat.
		m s	′ ″			m s	′ ″
May	1	−2 23.2	+11 56	May	17	−2 18.4	+11 16
	3	22.8	52		19	17.6	10
	5	22.3	47		21	16.7	11 04
	7	21.8	43		23	15.7	10 57
	9	21.2	38		25	14.7	51
	11	20.6	33		27	13.6	44
	13	19.9	27		29	12.4	37
	15	−2 19.2	+11 22		31	−2 11.2	+10 30

VARIABLE STARS.

Maxima of Variable Stars of Short Period.

[Calculated by members of the class in General Astronomy at Carleton College.]

Given to the nearest hour in Greenwich mean time. To obtain Eastern standard time subtract 5^h; Central standard time 6^h; etc.

Star	R. A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of maxima in 1919. May							
	h m	° ′		d h.	d h	d h	d h	d h				
SX Cassiop.	0 05.5	+54 20	8.6— 9.2	36 13.7	1 20							
SY Cassiop.	0 09.8	+57 52	9.3— 9.9	4 1.7	4 5;	8 7;	16 10;	24 14				
RR Ceti	1 27.0	+ 0 50	8.3— 9.0	0 13.3	4 19;	12 12;	20 6;	28 0				
RW Cassiop.	1 30.7	+57 15	8.9—11.0	14 19.2		15 12		30 7				
V Arietis	2 09.6	+11 46	8.3— 9.0	0 23.8	5 5;	13 3;	21 2;	29 0				
SU Cassiop.	2 43.0	+68 28	6.5— 7.0	1 22.8	6 18;	14 13;	22 8;	30 3				
TU Persei	3 01.8	+52 49	11.4—12.2	0 14.6	3 10;	10 17;	17 0;	25 7				
RW Camelop.	3 46.2	+58 21	8.2— 9.4	16 00.0	2 0		18 0					
SX Persei	4 10.2	+41 27	10.4—11.2	4 07.0	5 2;	13 16;	22 6;	30 20				
SV Persei	42.8	+42 07	8.8— 9.6	11 03.1		3 1;	14 5;	25 8				
RX Aurigae	4 54.5	+39 49	7.2— 8.1	11 15.0	3 11;	15 2		26 17				
SX Aurigae	5 04.6	+42 02	8.0— 8.7	1 12.8	1 16;	9 8;	17 0;	24 16				
SY Aurigae	05.5	+42 41	8.4— 9.5	10 03.3	1 19;	11 23;	22 2					
Y Aurigae	21.5	+42 21	8.6— 9.6	3 20.6	2 7;	9 24;	17 17;	25 10				
RZ Gemin.	5 56.6	+22 15	9.1—10.0	5 12.7	5 9;	16 11;	21 23;	27 12				
RS Orionis	6 16.5	+14 44	8.2— 8.9	7 13.6	8 4;	16 18;	24 7;	31 21				
T Monoc.	19.8	+ 7 08	5.7— 6.8	27 00.3		7 6						
RT Aurigae	23.0	+30 33	5.1— 6.0	3 17.5	8 1;	15 12;	22 23;	30 10				
RZ Camelop.	23.7	+67 06	11.0—13.0	0 11.5	4 10;	11 15;	18 20;	26 1				
W Gemin.	29.2	+15 24	6.7— 7.5	7 22.0	5 19;	13 17;	21 15;	29 13				
ζ Gemin.	6 58.2	+20 43	3.7— 4.3	10 03.7	4 23;	15 3		25 6				
RU Camelop.	7 10.9	+69 51	8.5— 9.8	22 06.5			17 7					

Maxima of Variable Stars of Short Period—Continued.

Star	R.A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of maxima in 1919. May
	h m	° ′		d h	d h; d h; d h; d h
RR Gemin.	7 15.2	+31 04	10.0—11.5	0 09.5	4 9; 12 7; 20 6; 28 5
V Carinae	8 26.7	−59 47	7.4— 8.1	6 16.7	4 10; 11 3; 17 19; 24 12
T Velorum	8 34.4	−47 01	7.6— 8.5	4 15.3	4 15; 13 22; 18 13; 23 5
V Velorum	9 19.2	−55 32	7.5— 8.2	4 08.9	6 3; 14 18; 19 3; 23 12
Z Leonis	9 46.4	+27 22	7.9— 9.6	59 00.0	
RR Leonis	10 02.1	+24 29	9.1—10.1	0 10.9	6 9; 13 4; 19 22; 26 17
SU Draconis	11 32.2	+67 53	8.9— 9.6	0 15.8	8 20; 15 11; 22 1; 28 16
S Muscae	12 07.4	−69 36	6.4— 7.3	9 15.8	9 11 19 3; 28 18
SW Draconis	12.8	+70 04	8.8— 9.6	0 13.7	3 5; 11 4; 19 4; 27 3
T Crucis	15.9	−61 44	6.8— 7.6	6 17.6	4 16; 11 10; 18 3; 24 21
R Crucis	18.1	−61 04	6.8— 7.9	5 19.8	8 3; 13 22; 19 18; 25 14
S Crucis	12 48.4	−57 53	6.5— 7.6	4 16.6	6 5; 10 21; 15 14; 24 23
W Virginis	13 20.9	− 2 52	8.7—10.4	17 06.5	7 11 24 17
SS Hydrae	25.0	−23 08	7.4— 8.1	8 4.8	6 15; 14 20; 23 0; 31 5
RV Urs. Maj.	13 29.4	+54 31	9.2— 9.9	0 11.2	9 0; 16 0; 23 1; 30 1
ST Virginis	14 22.5	− 0 27	10.3—11.4	0 09.9	5 14; 13 19; 22 1; 30 6
V Centauri	25.4	−56 27	6.4— 7.8	5 11.9	6 6; 17 5; 22 17; 28 5
RS Bootis	29.3	+32 11	8.9—10.0	0 09.1	5 0; 12 12; 20 2; 27 15
RU Bootis	14 41.5	+23 44	12.8—14.3	0 11.9	4 21; 12 7; 19 17; 27 3
R Triang. Austr.	15 10.8	−66 08	6.7— 7.4	3 09.3	5 23; 12 18; 19 13; 26 17
S Triang. Austr.	15 52.2	−63 29	6.4— 7.4	6 07.8	7 7; 13 15; 19 23; 26 7
S Normae	16 10.6	−57 39	6.6— 7.6	9 18.1	1 12; 11 6; 22 0; 30 18
RW Draconis	33.7	+58 03	9.6—10.8	0 10.6	5 17; 14 14; 18 0; 23 10
RV Scorpii	16 51.8	−33 27	6.7— 7.4	6 01.5	3 11; 15 14; 21 15; 27 17
X Sagittarii	17 41.3	−27 48	4.4— 5.0	7 00.3	8 21; 15 21; 22 21; 29 21
Y Ophiuchi	47.3	− 6 07	6.1— 6.5	17 02.9	3 15 20 18
W Sagittarii	17 58.6	−29 35	4.3— 5.1	7 14.3	7 14; 15 4; 22 18; 30 9
Y Sagittarii	18 15.5	−18 54	5.4— 6.2	5 18.6	6 15; 12 10; 23 23; 29 17
U Sagittarii	26.0	−19 12	6.5— 7.3	6 17.9	5 11; 12 5; 18 23; 25 17
Y Scuti	32.6	− 8 27	8.7— 9.2	10 08.3	1 13; 11 21; 22 6
Y Lyrae	34 2	+43 52	11.3—12.3	0 12.1	3 3; 15 4; 21 5; 27 6
RZ Lyrae	39.9	+32 42	9.9—11.2	0 12.3	3 8; 15 14; 21 18; 27 21
RT Scuti	18 44.1	−10 30	9.1— 9.7	0 11.9	3 19; 15 16; 21 15; 27 14
κ Pavonis	18 46.6	−67 22	3.8— 5.2	9 02.2	5 10; 14 12; 23 14
U Aquilae	19 24.0	− 7 15	6.2— 6.9	7 00.6	3 20; 10 21; 17 22; 24 22
XZ Cygni	30.4	+56 10	8.6— 9.3	0 11.2	6 22; 13 22; 20 22; 27 22
U Vulpec.	32.2	+20 07	6.5— 7.6	7 23.5	5 13; 13 12; 21 12; 29 11
SU Cygni	40.8	+29 01	6.2— 7.0	3 20.3	7 8; 15 0; 22 17; 30 10
η Aquilae	47.4	+ 0 45	3.7— 4.5	7 04.2	3 13; 10 17; 17 21; 25 2
S Sagittae	51.5	+16 22	5.6— 6.4	8 09.2	4 17; 13 23; 21 11; 29 21
X Vulpec.	19 53.3	+26 17	9.5—10.5	6 07.7	4 6; 10 14; 23 5; 29 13
X Cygni	20 39.5	+35 14	6.0— 7.0	16 09.3	7 12 23 21
T Vulpec.	47.2	+27 52	5.5— 6.1	4 10.5	7 16; 12 3; 21 0; 29 21
WY Cygni	52.3	+30 03	9.6—10.4	0 13.5	4 21; 11 15; 25 2; 31 19
RV Capric.	55.9	−15 37	9.2—10.1	0 10.7	8 10; 15 4; 21 21; 28 14
TX Cygni	20 56.4	+42 12	8.5— 9.7	14 17.4	14 23 29 16
VY Cygni	21 00.4	+39 34	8.8— 9.5	7 20.6	5 15; 13 12; 21 8; 29 5
SW Aquarii	10.2	− 0 20	9.9—10.8	0 11.0	5 0; 11 21; 18 18; 25 16
VZ Cygni	21 47.7	+42 40	8.2— 9.2	4 20.7	6 21; 16 15; 26 8; 31 5
Y Lacertae	22 05.2	+50 33	9.1— 9.6	4 07.8	9 5; 17 21; 26 13; 30 20
δ Cephei	25.5	+57 54	3.7— 4.6	5 08.8	6 20; 12 5; 23 22; 28 7
Z Lacertae	36.9	+56 18	8.2— 9.0	10 21.1	8 14 19 12; 30 9
RR Lacertae	37.5	+55 55	8.5— 9.2	6 10.1	7 11; 13 21; 20 7; 26 17
V Lacertae	44.5	+55 48	8.5— 9.5	4 23.6	4 16; 14 15; 19 15; 29 14
X Lacertae	22 45.0	+55 54	8.2— 8.6	5 10.7	7 5; 12 16; 23 13; 29 0
SW Cassiop.	23 03.7	+58 11	9.2— 9.7	5 10.6	6 1; 16 22; 22 9; 27 19
RS Cassiop.	32.6	+61 52	9.0—11.0	6 07.1	7 17; 14 0; 20 7; 26 14
RY Cassiop.	47.2	+58 11	9.3—11.8	12 03.4	11 9; 23 12
V Cephei	23 51.7	+82 38	6.0—7.0	0 23.9	3 17; 10 17; 17 16; 24 16

Minima of Variable Stars of Short Period.

[Calculated by D. C. Kazarinoff at Goodsell Observatory.]

Given to the nearest hour in Greenwich mean time; to obtain Eastern Standard time subtract 5h; Central Standard 6h; etc.

Star	R. A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of minima in 1919 May							
	h m	° ′		d h	d	h	d	h	d	h	d	h
SY Androm.	0 08.0	+43 09	9.5—13.0	34 21.8			11	4				
RT Sculptor.	31.5	−26 13	9.6—10.5	0 12.3	6	5;	13	22;	21	14;	29	7
UU Androm.	38.5	+30 24	10.7—11.9	1 11.7	7	16;	15	2;	22	13;	29	23
U Cephei	0 53.4	+81 20	7.0— 9.0	2 11.8	3	7;	10	18;	18	6;	25	17
Z Persei	2 33.7	+41 46	9.4—12	3 01.4	6	20;	12	22;	19	1;	24	4
TW Cassiop.	37.6	+65 19	8.2— 9.0	1 10.3	4	4;	11	8;	18	11;	25	15
RY Persei	39.0	+47 43	8.0—10.3	6 20.7	8	19;	15	16;	22	12;	29	9
RZ Cassiop.	39.9	+69 13	6.9— 8.1	1 04.7	4	20;	12	0;	19	4;	26	9
TX Cassiop.	44.4	+62 22	9.4—10.1	2 22.2	2	15;	11	9;	20	4;	28	23
ST Persei	53.7	+38 47	8.5—10.5	2 15.6	7	18;	15	16;	23	15;	31	14
RX Cassiop.	2 58.8	+67 11	8.6— 9.1	32 07.6					20	22		
Algol	3 01.7	+40 34	2.3— 3.5	2 20.8	5	13;	11	7;	22	18;	28	12
RT Persei	16.7	+46 12	9.5—11.5	0 20.4	3	11;	10	6;	23	20;	30	15
λ Tauri	55.1	+12 12	3.3— 4.2	3 22.9	4	23;	12	21;	20	18;	28	16
RW Tauri	3 57.8	+27 51	7.1—<11	2 18.5	6	13;	14	20;	23	3;	31	11
RV Persei	4 04.2	+33 59	9.5—11.0	1 23.4	8	3;	16	0;	23	22;	31	19
RW Persei	13.3	+42 04	8.8—11.0	13 04.8			11	8;	24	13		
SZ Tauri	31.4	+18 20	7.2— 7.7	3 03.6	1	8;	10	18;	20	5;	29	16
RS Cephei	4 48.6	+80 06	9.5—12.0	12 10.1	4	15;			17	1,	29	12
TT Aurigae	5 02.8	+39 27	7.8— 8.7	0 16.0	5	13;	12	5;	18	21;	25	13
RY Aurigae	11.5	+38 13	10.7—11.7	2 17.5	3	22;	12	2;	20	7;	28	11
RZ Aurigae	42.9	+31 40	10.6—13.3	3 00.3	7	16;	13	16;	25	17;	31	18
SV Tauri	45.8	+28 05	9.4—11.0	2 04.0	2	1;	10	17;	19	9;	28	1
Z Orionis	50.2	+13 40	9.7—10.7	5 04.9	5	11;	15	21;	21	1;	26	6
SV Gemin.	54.6	+24 28	9.8—<11	4 00.2	5	11;	13	11;	21	11;	29	12
RW Gemin.	5 55.4	+23 08	9.5—11.0	2 20.8	3	6;	14	7;	26	4;	31	21
U Columbae	6 11.2	−33 03	9.2—10.0	2 19.2	6	10;	12	0;	23	5;	28	19
SX Gemin.	22.0	+20 37	10.8—11.5	1 08.8	8	17;	16	22;	21	0;	25	3
RW Monoc.	29.3	+ 8 54	9.0—10.8	1 21.7	8	12;	16	3;	23	18;	31	9
RX Gemin.	43.6	+33 21	8.8— 9.6	12 05.0	5	5;			17	10;	29	15
RU Monoc.	6 49.4	− 7 28	9.8—10.5	0 21.5	2	21;	10	1;	24	9;	31	13
R Can. Maj.	7 14.9	−16 12	5.8— 6.4	1 03.3	3	21;	10	17;	24	8;	31	4
RY Gemin.	21.7	+15 52	8.9—<10	9 07.2	9	23			19	6;	28	13
Y Camelop.	27.6	+76 17	9.5—12	3 07.3	5	11;	12	2;	25	7;	31	22
TX Gemin.	30.3	+17 8	10.0—11.9	2 19.2	3	20;	12	5;	20	15;	29	0
RR Puppis	43.5	−41 08	9.4—10.7	6 10.3	3	4;	16	14;	22	11;	28	21
V Puppis	7 55.4	−48 58	4.1— 4.8	1 10.9	3	17;	10	23;	18	6;	25	12
X Carinae	8 29.1	−58 53	7.9— 8.7	0 13.0	6	8;	14	10;	22	13;	30	16
S Cancri	8 38.2	+19 24	8.2—10	9 11.6	5	21;	15	8;	24	20		
RX Hydrae	9 00.8	− 7 52	9.1—10.5	2 6.8	6	5;	13	2;	19	22;	26	18
S Velorum	29.4	−44 46	7.8— 9.3	5 22.4	3	3;	15	0;	20	22;	26	20
Y Leonis	9 31.1	+26 41	9.3—11.2	1 16.5	8	14;	15	8;	22	1;	28	19
RR Velorum	10 17.8	−41 36	10.0—10.9	1 20.5	7	13;	14	23;	22	9;	29	19
SS Carinae	10 54.2	−61 23	12.2—12.8	3 07.2	3	8;	9	22;	23	3;	29	17
ST Urs. Maj.	11 22.4	+45 44	6.7— 7.2	8 19.2	4	10;	13	5;	22	0;	30	19
RW Urs. Maj.	35.4	−52 34	10.3—11.4	7 07.9	8	6;	15	14;	22	21;	30	5
Z Draconis	11 39.8	+72 49	9.9—13.6	1 08.6	8	14;	15	9;	22	4;	28	23
RZ Centauri	12 55.6	− 64 05	8.5— 8.9	1 21.0	5	20;	13	8;	20	20;	28	8
RS Can. Ven.	13 06.3	+36 28	7.5—12.5	4 19.1	3	1;	12	15;	22	5;	31	20
SS Centauri	13 07.2	−63 37	8.8—10.4	2 11.5	2	14;	10	0;	17	11;	24	21
133926 Hydrae	13 39.0	−26 23	8.6—12.7	2 21.5	3	2;	14	16;	20	11;	26	6
δ Librae	14 55.6	− 8 07	4.8— 6.2	2 07.9	5	7;	12	7;	19	6;	26	6

Minima of Variable Stars of Short Period—Continued.

Star	R. A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of minima in 1919 May							
	h m	° ′		d h	d h	d h	d h	d h	d h	d h	d h	
U Coronae	15 14.1	+32 01	7.6— 8.7	3 10.9	6 2;	13 00;	19 22;	26 20				
TW Draconis	32.4	+64 14	7.3— 8.9	2 19.3	1 16;	10 2;	18 13;	26 23				
SS Librae	15 43.4	−15 14	9.3—11.5	0 18.4	2 10;	10 1;	17 17;	25 9				
SW Ophiuchi	16 11.1	− 6 44	9.2—10.0	2 10.7	3 1;	10 9;	17 17;	25 1				
SX Ophiuchi	12.6	− 6 25	10.5—11.2	2 01.5	5 9;	13 15;	21 21;	30 4				
R Arae	31.1	−56 48	6.8— 7.9	4 10.2	8 18;	17 15;	25 11;	29 21				
TT Herculis	16 49.9	+17 00	8.9— 9.3	20 18.1	7 22;	17 14		28 16				
TU Herculis	17 09.8	+30 50	9.5—12	2 06.4	8 1;	14 20;	21 15;	28 10				
U Ophiuchi	11.5	+ 1 19	6.0— 6.7	0 20.1	8 13;	16 23;	25 8;	28 17				
u Herculis	13.6	+33 12	4.6— 5.4	2 01.2	5 10;	11 14;	23 21;	30 1				
TX Herculis	15.4	+42 00	8.3— 9.0	1 00.7	2 20;	10 1;	17 6;	24 11				
RV Ophiuchi	29.8	+ 7 19	9. —12	3 16.5	8 11;	15 20;	23 5;	30 14				
SZ Herculis	36.0	+33 01	9.5—10.3	0 19.6	7 15;	15 20;	24 0;	28 2				
TX Scorpii	48.6	−34 13	7.5— 8.2	0 22.6	4 3;	11 15;	19 4;	26 17				
UX Herculis	49.7	+16 57	8.8—10.5	1 13.2	6 2;	13 20;	21 14;	29 8				
Z Herculis	53.6	+15 09	7.1— 7.9	3 23.8	3 1;	11 0;	19 0;	27 0				
WX Sagittae	53.6	−17 24	9.2—10.8	2 03.1	6 16;	15 20;	23 17;	27 23				
WY Sagittae	17 54.9	−23 1	9.5—10.6	4 16.0	7 9;	16 17;	26 1;	30 17				
SX Draconis	18 03.0	+ 58 23	9.3—10.5	5 04.1	5 17;	16 1;	21 5;	26 9				
RS Sagittarii	11.0	−34 08	5.9— 6.3	2 10.0	7 15;	14 20;	22 2;	29 8				
V Serpentis	11.1	−15 34	9.5—11.1	3 10.9	3 23;	10 21;	17 18;	24 16				
RZ Scuti	21.1	− 9 15	7.4— 8.3	15 03.2		11 19		26 22				
RZ Draconis	21.8	+58 50	9.5—10.2	0 13.2	9 0;	16 4;	23 8;	30 12				
RX Herculis	26.0	+12 32	7.0— 7.6	0 21.3	3 19;	10 22;	18 1;	25 3				
SX Sagittarii	39.7	−30 36	8.7— 9.8	2 01.8	6 15;	14 22;	23 6;	31 13				
RR Draconis	40.8	+62 34	9.3—13	2 19.9	1 4;	9 15;	18 3;	26 15				
RS Scuti	43.7	−10 21	9.3—10.3	0 15.9	8 18;	15 10;	22 1;	28 17				
β Lyrae	46.4	+33 15	3.4— 4.1	12 21.8	4 4;	17 2		30 0				
U Scuti	18 48.9	−12 44	9.1— 9.6	0 22.9	1 13;	9 4;	16 19;	24 11				
RX Draconis	19 01.1	+58 35	9.3—10.2	1 21.4	1 3;	8 16;	16 6;	23 20				
RV Lyrae	12.5	+32 15	11. —12.8	3 14.4	7 1;	14 5;	21 10;	28 15				
RS Vulpec.	13.4	+22 16	6.9— 8.0	4 11.4	4 18;	13 17;	22 16;	31 15				
U Sagittae	14.4	+19 26	6.5— 9.0	3 09.1	7 9;	14 3;	20 22;	27 16				
Z Vulpec.	17.5	+25 23	7.3— 8.5	2 10.9	1 16;	9 1;	16 10;	23 19				
TT Lyrae	24.3	+41 30	9.4—11.6	5 05.8	3 6;	13 18;	19 00;	29 6				
UZ Draconis	26.1	+68 44	9.0— 9.8	1 15.1	8 4;	14 16;	21 5;	27 17				
SY Cygni	19 42.7	+32 28	10 —12	6 00.2	7 16;	13 16;	19 16;	25 16				
WW Cygni	20 00.6	+41 18	9.3—13.4	3 07.6	8 6;	14 22;	21 13;	28 4				
SW Cygni	03.8	+46 01	9. —11.7	4 13.8	1 21;	11 0;	20 4;	29 7				
VW Cygni	11.4	+34 12	9.8—11.8	8 10.3	2 6;	10 16;	19 3;	27 13				
RW Capric.	12.2	−17 59	8.8—10.6	3 09.4	6 23;	13 17;	20 12;	27 7				
UW Cygni	19.6	+42 55	10.5—13	3 10.8	6 0;	12 22;	19 19;	26 17				
V Vulpec.	32.3	+26 15	8.2—9.8	37 19.0								
W Delphini	33.1	+17 56	9.4—12.1	4 19.4	2 12;	12 3;	21 17;	31 8				
RR Delphini	38.9	+13 35	10.5—11.8	4 14.4	9 5;	18 10;	23 0;	27 14				
Y Cygni	48.1	+34 17	7.1— 7.9	1 12.0	6 4;	13 15;	21 3;	28 15				
WZ Cygni	49.3	+38 27	9.9—10.8	0 14.0	3 5;	10 19;	18 19;	25 0				
RR Vulpec.	20 50.5	+27 32	9.6—11.0	5 01.2	6 6;	16 9;	21 10;	26 11				
VV Cygni	21 02.3	+45 23	12.1—13.8	1 11.4	6 18;	14 4;	21 13;	28 22				
AE Cygni	09.0	+30 20	10.8—11.4	0 23.3	2 17;	12 9;	22 2;	31 18				
RY Aquarii	14.8	−11 14	8.8—10.4	1 23.2	6 5;	14 1;	21 22;	29 19				
RT Lacertae	21 57.4	+43 24	9.1—10.5	5 01.7	3 13;	13 16;	23 19;	28 21				
UZ Cygni	55.2	+43 52	8.9—11.6	31 07.3		19 11						
RW Lacertae	22 40.6	+49 08	10.2—11.2	5 04.4	5 14;	15 23;	21 4;	26 8				
TT Androm.	23 08.7	+45 36	11.3—12.6	2 18.4	5 10;	13 17;	22 0;	30 7				
Y Piscium	29.3	+ 7 22	9.0—12.0	3 18.3	8 9;	15 21;	23 10;	30 23				
TW Androm.	23 58.2	+32 17	8.6—11.5	4 02.9	4 12;	12 18;	21 0;	29 6				

NOTES FOR OBSERVERS.

Monthly Report of the American Association of Variable Star Observers, February, 1918.

EDWARD CHARLES PICKERING.

It is not often that an organization, working along scientific lines in a very restricted field, is blessed with the opportunity of enjoying a warm comradeship among its members—a keen fellowship and good will that proves a perennial inspiration, strengthens its purpose, and furthers its accomplishment. In this regard, the American Association of Variable Star Observers is unique.

Today its members, in many parts of the world, stand shocked and silent with the sense of a great loss.

Professor Edward C. Pickering, founder and friend, is gone. No one can ever replace him in the activities of the Association or in the hearts of its members. They had referred to him often as the "Big Brother," and this name, perhaps better than any other, conveys his attitude most truly to the mind. His interest and patient helpfulness in every act of the Association endeared him to its members, and his singleness of purpose in advancing the cause of science in no wise mitigated against his genial comradeship.

His sense of humor was marked and added not a little to the charming grace of the hospitality which, each autumn, he extended to the members of the Association. It is as he was on these occasions that the moving pictures of memory shall most clearly recall him to his friends of the A. A. V. S. O.

Nothing in his career stands out more brightly than his constant and sympathetic endeavor to aid the amateur to progress along that trail which he himself had blazed as a pioneer.

His was the simplicity, the modesty, and the gentleness of the truly great.

The world of Astronomy has lost a Master Mind.

Our Association has lost a loved and loyal friend.

DAVID B. PICKERING.

By request, Mr. D. B. Pickering has contributed the above appreciation, to which all our members will subscribe. The Association will be glad to know that, during Professor Pickering's illness and at the services, flowers were sent in the name of the A. A. V. S. O., that our members were represented at the funeral by Messrs. Burbeck, Jordan, and Schulmaier, as well as the members of the Observatory Staff.

Attention is called to the decrease in the number of observations contributed during the past few months. This is, in part, due to the excessive amount of cloudy

Variable Star Observations, February, 1919

January 0, 1919 = 2421959 February 0 = 2421990 March 0 = 2422018

001046
X Androm.
J.D. Est. Obs.
242
1997.6 8.6 Hu
2009.5 9.0 V

001726
T Androm.
2014.5<11.2 Pi

001838
R Androm.
1992.6 11.3 Hu
2014.5 11.6 Pi

004047
U Cassiop.
2007.6<12.8 Y

004132
RW Androm.
2006.6 8.6 Wh

004435
V Androm.
1992.6<12.6 Hu

004958
W Cassiop.
1992.6 9.4 Hu
2006.6 10.9 Wh

011208
S Piscium
2010.5<13.0 Y

012350
RZ Persei
2008.6 10.5 Y

012502
R Piscium
2010.5<12.3 Y

013238
RU Androm.
1997.6 10.9 Hu
2006.6 11.3 Wh

014958
X Cassiop.
2007.6 12.6 Y
14.6 11.5 Pi

015354
U Persei
1991.6 10.2 Wh
97.6 10.0 Hu
2014.6 10.4 Pi

021024
R Arietis
1992.6 12.0 Hu

021281
Z Cephei
2009.6<12.0 V

021403
o Ceti
J.D. Est.Obs.
242
1997.6 7.5 Hu
2009.6 9.0 Pt

022150
RR Persei
2007.6 11.3 Y
14.6 11.9 Pi

022813
U Ceti
1993.5 8.3 Y

023133
R Triang.
1997.6 6.6 Hu
2008.6 5.6 Wh
14.6 5.5 Pi

024356
W Persei
1991.6 10.3 Wh
91.7 9.4 Mu
92.6 9.2 Hu
2008.6 9.5 Pt
12.7 9.9 Mu
14.6 9.5 Pi

030514
U Arietis
1993.5 12.5 Y
2008.6 12.1 Y

032043
Y Persei
1992.6 8.2 Hu
2008.6 8.6 Pt
12.7 8.6 Mu
14.6 9.2 Pi

032335
R Persei
1992.6 12.5 Hu
2014.6 10.8 Pi

033362
U Camelop.
1996.7 7.5 Wh
2014.6 8.2 Pi

042215
W Tauri
1991.7 9.4 Mu
96.6 9.7 Yo
97.6 9.0 Hu
2006.6 9.1 Wh
09.6 9.8 V
10.5 9.6 Y
12.7 9.9 Mu
13.6 10.0 B
17.5 9.9 Pi

042209
R Tauri
J.D. Est.Obs.
242
1997.6 9.0 Hu
2006.6 10.2 Wh
10.5 9.3 Y
13.6 9.4 B
14.5 9.7 Yo
15.6 9.7 Pt

042309
S Tauri
2010.5<12.8 Y

043065
T Camelop.
1996.6 10.5 Wh
2017.6 9.4 Wh

043274
X Camelop.
1995.6 11.5 Wh
2008.5 12.5 Y
16.6 12.6 Hu

044617
V Tauri
2002.6 10.4 Yo
17.5 9.1 Pi

045307
R Orionis
2008.6 12.1 Y

045514
R Leporis
1998.7 7.0 B
99.6 7.8 My
2008.7 7.7 Pt
09.3 7.9 My
16.5 7.8 My

050003
V Orionis
1998.6 10.2 B
2008.6 11.3 Wh
08.6 10.7 Y

050022
T Leporis
1998.7 8.0 B

050953
R Aurigae
2009.6 8.0 V
17.5 8.5 Pi

052034
S Aurigae
2017.5 10.0 Pi
17.6 9.7 Wh

052404
S Orionis
2014.5 10.0 Y

053068
S Camelop.
J.D. Est.Obs.
242
2017.7 8.6 Wh

*053005*a
T Orionis
1991.6 9.9 Mu
97.6 10.0 Hu
2006.6 9.9 Wh
11.6 10.2 B

053531
U Aurigae
2007.6 10.0 Y
09.6 9.5 V
17.6 10.2 R

054319
SU Tauri
1991.6 9.5 Wh
95.8 9.5 M
98.7 9.4 B
2009.6 9.6 Hu
09.6 9.5 V
09.6 9.6 Wh
10.5 9.5 Y
13.5 9.5 B
14.7 9.6 Pi
17.6 9.5
17.7 9.6 Wh

054615a
Z Tauri
2008.6<12.7 Y

054615b
RS Tauri
2008.6 8.8 Y

054615c
RU Tauri
2008.6 12.2 Y

054974
V Camelop.
1995.8 12.8 M
2008.6 12.6 Y

054920
U Orionis
1991.7 11.4 Mu
95.8 12.2 M
97.6 11.6 Hu
98.6 11.6 B

055353
Z Aurigae
1995.8 10.7 M
2014.7 10.3 Pi

060450
X Aurigae
1996.7 8.4 Wh
2014.7 8.8 Pi
15.6 9.0 Pt
16.6 8.3 Hu

060547
SS Aurigae
J.D. Est. Obs.
242
1993.5 10.9 Y
95.8 11.5 M
96.7 12.0 Wh
96.9 12.0 M
97.6 12.7 Y
2014.7<12.4 Pi
17.6<11.7

061647
V Aurigae
1995.8 10.7 M
2017.6 11.6 Pi

061702
V Monoc.
2009.6 8.9 Hu

063159
U Lyncis
1995.8 9.7 M
2008.6 10.0 Y
17.6 9.8 Pi

063308
R Monoc.
2013.6 11.2 B

063558
S Lyncis
2017.6 11.2 Pi

064707
W Monoc.
1998.7 10.8 B

065111
Y Monoc.
2009.5 10.6 Y
09.6 9.8 V
13.6 10.3 B

065208
X Monoc.
2009.6 8.5 Hu

065355
R Lyncis
2008.6 10.7 Y

070122a
R Gemin.
2009.6 8.9 Hu
16.5 9.8 Pi
16.6 9.7 Wh

070310
R Can. Min.
2009.6 8.5 Hu
13.6 8.4 B
16.5 9.1 Pi

VARIABLE STAR OBSERVATIONS, February, 1919—Continued.

072708
S Can. Min.

J.D. 242	Est.	Obs.
1992.5	11.9	Yo

073508
U Can. Min.

2009.5	10.3	Y

073723
S Gemin.

2016.5	12.6	Pi

074323
T Gemin.

2008.6	10.4	Wh
09.6	9.9	Hu
13.6	10.2	V

074922
U Gemin.

1992.5	<12.7	Yo
93.6	<13.7	Y
2009.6	<13.0	Hu
09.6	<13.3	Y
10.6	<13.3	Yo
13.6	<11.7	V
14.7	<12.3	Pi
16.6	<13.5	Yo
24.6	<13.5	Jd

081112
R Cancri

2009.6	8.9	Hu
09.6	9.3	Wh
14.7	9.4	Pt
15.6	8.8	B
16.6	9.3	Pi
24.5	8.6	Jd

081633
T Lyncis

2009.6	8.3	Hu

081617
V Cancri

2008.7	7.9	Pt
09.6	8.1	Wh
13.7	8.0	B
14.5	8.9	My
16.5	8.9	
16.6	8.5	Pi

084803
S Hydrae

2009.6	12.3	Hu

085008
T Hydrae

2015.6	7.9	Pt

085120
T Cancri

2009.6	10.3	Wh

090151
V Urs. Maj.

J.D. 242	Est.	Obs.
1991.7	10.2	Mu
2012.7	10.1	
16.6	9.7	Hu

093178
Y Draconis

2008.6	9.0	Y

093934
R Leo. Min.

2008.7	7.4	Pt
09.6	7.6	Hu
24.6	7.9	Jd

094211
R Leonis

1996.6	9.7	Wh
2008.7	9.3	Pt
12.7	9.4	Mu
16.6	8.9	Wh
17.8	9.2	M
21.6	9.3	Jd_2

094622
Y Hydrae

2015.7	7.0	Pt

095421
V Leonis

2016.6	12.8	Hu
17.8	12.8	M

103769
R Urs. Maj.

2006.5	10.8	Pi
12.7	10.4	Mu
15.6	9.7	Pt
16.6	9.0	Hu
17.8	9.5	M

104620
V Hydrae

2015.7	7.0	Pt

104814
W Leonis

1993.6	11.2	Y
2010.6	11.4	Y
17.8	12.2	M

115919
R. Com. Ber.

2017.8	<12.5	M

122001
SS Virginis

1969.8	7.8	M

122532
T Can. Ven.

1969.9	11.5	M
2016.7	11.6	Wh

122803
Y Virginis

1996.8	9.3	M

123160
T Urs. Maj.

J.D. 242	Est.	Obs.
1993.6	7.5	Y
95.8	7.6	M
96.6	7.1	Wh
2006.5	7.0	Pi
08.6	7.0	Pt

123307
R Virginis

1996.8	10.3	M
2024.6	8.3	Jd

123459
RS Urs. Maj.

1995.8	<13.3	M

123961
S Urs. Maj.

1993.6	8.3	Y
95.8	8.2	M
96.6	8.0	Wh
2006.5	7.4	Pi
08.6	7.5	Pt
12.7	8.4	Mu

124606
U Virginis

2014.7	8.3	Pt

132706
S Virginis

1996.8	6.4	M
2014.8	7.1	Pt

133273
T Urs. Min.

2017.9	10.0	M

134440
R Can. Ven.

1991.6	11.9	Y
96.8	11.2	M
2014.7	11.0	Yo

140113
Z Bootis

1995.9	10.3	M

142539
V Bootis

1996.8	9.1	M
2015.7	8.9	Pt
16.7	9.8	Wh

143227
R Bootis

1996.8	10.0	M
2016.7	11.3	Wh

144918
U Bootis

1996.8	10.8	M

151731
S Cor. Bor.

J.D. 242	Est.	Obs.
1996.8	6.7	M

154428
R Cor. Bor.

1994.9	5.9	Pt
95.8	6.0	M
95.9	5.9	Pt
96.8	6.0	M
2014.8	5.9	Pt
14.8	6.8?	Yo
15.7	6.0	Pt
17.7	6.0	

154536
X Cor. Bor.

1995.8	11.3	M

154639
V Cor. Bor.

1995.8	8.3	M
2016.8	9.0	M

154615
R Serpentis

2014.8	8.8	Pt
16.8	8.5	M

160625
RU Herculis

2016.9	8.3	M

*161122*a
R Scorpii

2017.9	<12.4	M

*161122*b
S Scorpii

2017.9	<12.4	M

*161122*c
T Scorpii

2017.9	10.8	M

162119
U Herculis

2016.8	11.4	M

163172
R Urs. Min.

2016.8	9.7	M
17.7	9.7	Wh

163137
W Herculis

2016.8	10.3	M

163266
R Draconis

2016.8	11.5	M

164055
S Draconis

J.D. 242	Est.	Obs.
2014.9	9.1	Pt
16.8	8.9	M

165631
RV Herculis

2017.8	<12.7	M

171723
RS Herculis

2016.8	12.4	M

*175458*a
T Draconis

2017.9	10.0	M

180531
T Herculis

2016.9	9.2	Pt
17.9	9.0	M

181136
W Lyrae

2017.9	10.6	M

184205
R Scuti

1994.9	5.0	Pt
95.9	5.2	
2014.9	5.3	
16.9	5.6	

184300
Nova Aquilae

1994.9	5.8	Pt
95.5	5.8	
2014.9	5.9	
16.9	6.3	

193732
TT Cygni

2014.9	7.8	Pt

200938
RS Cygni

2016.9	8.9	Pt

202954
ST Cygni

2010.5	<12.6	Y

203226
V Vulpeculae

2016.9	9.1	Pt

210382
X Cephei

1993.6	13.2	Y
2014.5	13.5	Y

210868
T Cephei

2008.6	6.5	Pt

VARIABLE STAR OBSERVATIONS, February 1919—Continued.

213678 S Cephei			SS Cygni		213937 RV Cygni			230759 V Cassiop.			235350 R Cassiop.	
J.D. 242	Est.	Obs.	J.D. 242	Est. Obs.	J.D. 242	Est.	Obs.	J.D. 242	Est.	Obs.	J.D. 242	Est. Obs.
2017.6	10.0	Wh	2009.6	8.7 Pt	2016.9	7.9	Pt	1991.6	9.6	Mu	2009.5	<11.4 V
			10.5	9.3 Y				92.6	9.4	Hu	235939 SV Androm.	
			14.5	9.2 Y				96.6	9.8	Wh		
213843 SS Cygni			15.6	8.9 Pt	230110 R Pegasi			2009.5	10.3	V	1992.6	8.0 Hu
			16.9	9.1 Pt				233335 ST Androm			93.5	8.1 Y
1993.5	11.5	Y			1993.5	9.3	V				2006.6	9.3 Wh
2009.5	9.1	Y						1992.6	9.0	Hu	09.5	8.3 Y

No. of Observations 305; No. of Stars Observed 131; No. of Observers 12.

weather which has prevailed during a greater part of that time; but, notwithstanding the decided improvement in this direction during February, our lists are comparatively few in number. Fortunately, the material supplied from other sources fills in the gaps which would otherwise occur in the light curves.

SS Aurigae, 060547, and U Geminorum, 074922, require careful watching during the next few months. SS Cygni, 213843, was well observed, in spite of its unfavorable position, and can now be best observed after midnight.

As will be noted from the observations of Mr. Peltier, Nova Aquila No. 3. can be well observed in the eastern sky shortly before sunrise, and, although frequent observations are not needed as in its earlier history, occasional observations are desired to follow its slowly decreasing curve.

The following Maxima for April are given from Harvard Circular 212:—

021024	R Arietis	Apr. 21	053068	S Camelopard.	Apr. 25
023080	RR Cephei	" 14	065355	R Lyncis	" 28
042309	S Tauri	" 11	081112	R Cancri	" 16
043065	T Camelopard.	" 9	083350	X Urs. Maj.	" 5
052404	S Orionis	" 7	094211	R Leonis	" 27

Mr. F. H. Spinney has returned from active military service, and may soon be counted on to contribute observations as valuable as in pre-war times.

Mr. McAteer and Miss Young have contributed excellent reports for this month.

Messrs. M. J. Jordan of Boston and L. D. Yont of Harvard University contribute for the first time to our reports, their designations being "Jd" and "Yo", respectively.

The spring meeting of our Association will be held on Saturday, May 3, 1919, at the home of Mr. D. B. Pickering, 171 South Burnett Street, East Orange, New Jersey. It is hoped that all who can will be present, for there are many things which need action.

Our Secretary, who spent a delightful month at Hot Springs, Arizona, will be in Los Angeles, California, during the month of March.

The following observers contributed to this report:—Messrs. Bouton, Hunter, Jordan, McAteer, Mundt, Murray, Peltier, D. B. Pickering, Vrooman, Whitehorn, Yont and Miss Young.

IDA E. WOODS.
Acting Secretary.

COMET AND ASTEROID NOTES.

Ephemeris of Wolf's Comet.

[From the *Astronomical Journal* 746. Continued from page 197.]

Berlin Noon	α	δ	log r	log Δ	Aberration Time
	h m s	° ′ ″			m s
May 1	4 49 34.9	+5 58 22	0.3176	0.4499	23 25
5	4 58 38.1	+6 06 08	0.3225	0.4564	23 46
9	5 07 36.0	12 11	0.3273	0.4627	24 06
13	16 28.4	16 32	0.3320	0.4689	24 26
17	25 15.2	19 10	0.3368	0.4719	24 47
21	33 56.3	20 05	0.3415	0.4808	25 08
25	42 31.8	19 18	0.3462	0.4864	25 28
29	51 01.6	16 49	0.3509	0.4919	25 47
June 2	5 59 25.2	12 39	0.3556	0.4971	26 06
6	6 07 43.2	+6 06 49	0.3602	0.5022	26 24
10	15 54.6	+5 59 22	0.3648	0.5070	26 42
14	23 59.7	50 19	0.3693	0.5118	27 00
18	31 58.4	39 45	0.3738	0.5163	27 17
22	39 50.7	27 35	0.3783	0.5205	27 33
26	47 36.6	+5 13 57	0.3827	0.5246	27 48
30	6 55 15.8	+4 58 52	0.3871	0.5285	28 03
July 4	7 02 48.2	42 23	0.3914	0.5322	28 17
8	7 10 13.6	+4 24 30	0.3957	0.5356	28 31

COMMUNICATIONS.

A Possible Relation between Equinoctial Precession and the Sun's Motion in Space.—We live in a universe of three dimensions: length, breadth and depth (thickness). It has become an axiom of science that gravitation is universal and instantaneous in its operation. The earth and moon; sun, planets and satellites; binary stars; star clusters; the all-encircling Milky Way are all subject to gravitation, are all to be pictured as influencing one another to the end of an adjusted equilibrium, constantly changing yet constantly maintained. All cosmic bodies are affected by the gravitational force of the universe as a whole and that composite gravitational force determines their motions. Like eddies or whirlpools in the ocean stellar bodies in close neighborhood may move as a gravitational unit or a combination of units, though not independently of the aggregate gravitational stress beyond their boundaries.

During the past one hundred years, patient and laborious observation has established the fact that the sun is in motion in the direction of Lyra-Hercules, or, more particularly, towards R. A. 270°. This fact justifies the inference that, gravitation being universal, the solar motion itself is controlled thereby and therefore that the sun's motion is curvilinear and not rectilinear. What then is the nature of the curve of the sun's orbit? It is respectfully suggested that this curvilinear motion of the sun is connected with the precession of the equinoxes. Considering that the sun's motion in space was unknown, unsuspected, in Newton's day, it is certainly no discredit to that eminent mathematician that he evolved his exceedingly ingenious theorem

to account for precession. He postulated an imaginary ring surrounding the earth and estimated that such a ring would have nodes on the ecliptic similar to the nodes of the moon's orbit. This idea he used as a working hypothesis to explain the equinoctial precession and likened the equatorial protuberance of the earth to a fixed ring which under the gravitational sway of the sun and the moon, vigorously modified by the centrifugal force of the earth's rotation, produced the precession at the rate of 50″.2 per annum, thus completing a circle in 25,900 years. May it not be questioned whether the precession of the equatorial protuberance (which, be it observed, is not an evenly moulded ring) and the precession of the nodes of planetary orbits are nearly identical phenomena? May it not be seriously considered whether, after all, the alleged motion of the equinoxes be in fact not a real slipping of the equator along the ecliptic westward (contra clockwise) but rather due to the constantly changing position of the solar system moving westward at the rate of 50″.2 per anum, the equinoctial points themselves being fixed and rigid but gradually changing their position as projected on the celestial sphere? An inspection of the

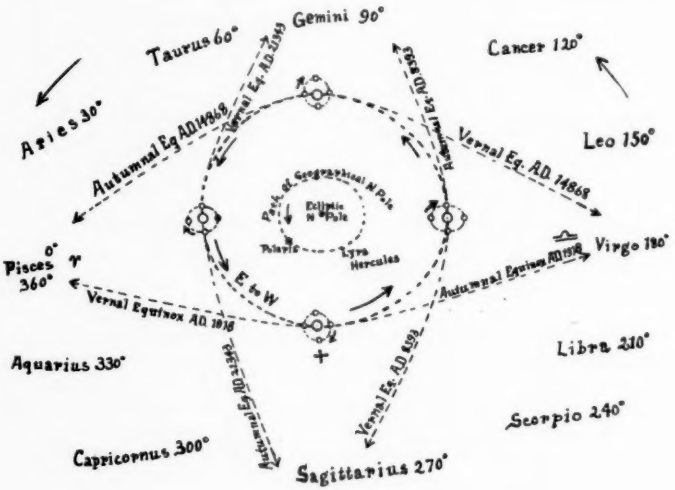


diagram may help to visualize this suggestion. At present ♈ and ♎ are respectively in the zodiacal constellations Pisces and Virgo. The R. A. of Pisces is 0° or 360°; that of Virgo is 180°. Twenty-one hundred years ago ♈ and ♎ were in the constellations Aries and Libra, which then had the same right ascensions as Pisces and Virgo have today, so that the sun was at that time also moving in the direction of 270° right ascension. Twenty-one hundred years hence ♈ and ♎ will be in Aquarius and Leo respectively and then their right ascensions will be the same respectively as those of Pisces and Virgo today, and the sun will still be moving towards 270° right ascension. To some readers this suggestion may seem to be purely speculative, perhaps uselessly speculative, but the fact of the sun's motion together with the strong presumption that it is curvilinear and the fact that the celestial pole moves round the ecliptic pole *in the same direction* as the sun's

motion would seem to indicate more than a chance coincidence and suggest that the 50″.2 registers the arc of orbit traversed by the solar system, considered as a unit, in one year and not an actual shift or slide of the earth's equator along the ecliptic.

OBJECTIONS: 1. If it be objected that the 23½° inclination of the equator to the ecliptic is peculiar to the earth and not shared by the other planets the answer is offered that according to the hypothesis here set forth whatever the inclinations of the other planets may be to the ecliptic they would all keep step proportionately with the earth's precession in encircling the ecliptic pole.

2. If it be objected that in the nature of the case luni-solar precession is necessarily very slow, it may be advisable to remember that, according to the accepted theory, the tides are occasionally the combined gravitational pull of the sun and the moon, the moon's differential attraction being 4 times greater than that of the sun. Tides are diurnal, with monthly variations due to the changing configuration of the sun and the moon with respect to the earth. Why, it may be asked, if the luni-solar attraction accounts for a complete cycle of tidal activity in the brief time of one day with monthly periodical variations, should not the same luni-solar attraction produce a similarly rapid precession of the equinoxes—or, at least a more rapid precession than the calculated rate of one complete cycle in 25,900 years?

3. If it be objected that 25,900 years are altogether too brief a period for one revolution of the sun in its orbit—(which orbit, by the way, should not be considered as a closed circle or ellipse but an open spiral)—it may be said in reply that no standard rate for the completion of a stellar orbit has yet been determined or estimated. If spiral nebulae are members of our sidereal universe their amazing velocities of revolution as reported by Slipher would justify the inclusion of the so-called "runaway" stars as members of our own system. Moreover stellar orbits may be of any proportion, big or little, within the range of the total gravitational force of the sidereal universe. Finally, it may be added that nutation, the varying eccentricities of planetary orbits and apsidal motions remain phenomena resulting from planetary perturbations and are therefore untouched by this hypothesis.

REV. W. E. GLANVILLE.

St. Peter's Rectory.
Solomons, Md.,
1918, Dec. 5.

Sextant Observations of Nova Aquilae 3.—In reply to your request of February 21, I send you herewith my sextant observation and computation for the apparent position of Nova Aquilae 3.

It may interest some of you readers, as I believe it to be an unusual method for the purpose, and in addition it shows the capabilities of the sextant as an astronomical instrument for the amateur.

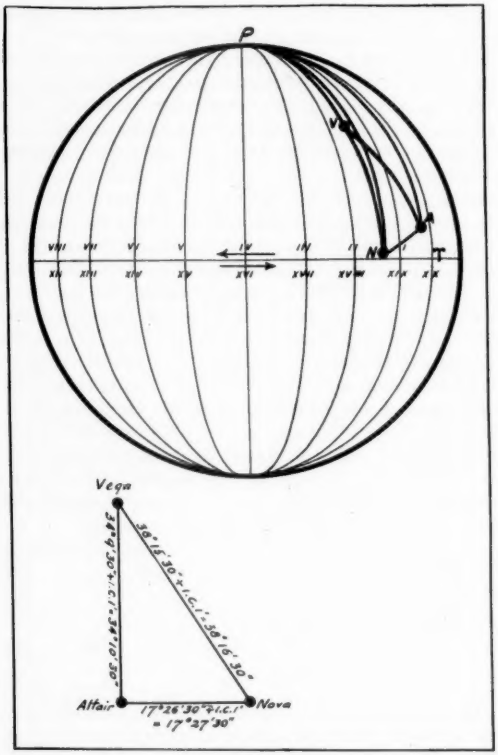
From my own experience I have always claimed that a sextant is superior to an ordinary transit for all astronomical problems of position, and this observation, when compared with similar ones made by different observers with transits, only confirms that claim.

The method you will observe is independent of time, azimuth, altitude (ignoring refraction) and latitude, and might therefore be used, for example at sea when those factors are usually indeterminate.

OBSERVATIONS OF NOVA AQUILAE No. 3.

Interstellar distances measured about 11:45 p. m. June 14, 1918, with a K&E sextant reading to 30″.

Vega —Altair, $VA = 34° 10' 30''$
Vega —Nova, $VN = 38 16 30$
Altair—Nova, $AN = 17 27 30$



	R. A.	Decl.
Position of Vega	$18^h\ 34^m\ 13^s$	$+38° 42' 24''$
" " Altair	19 46 50	+ 8 39 09

COMPUTATION.

I. In triangle PVA we know sides PV and PA and angle VPA. Solving for angle VAP we get

$$VAP = 25° 38' 08''.$$

II. In triangle VNA we know the three sides VA, NV and AN. Solving for the angle VAN we get

$$VAN = 91° 25' 03''.$$

III. In triangle NPA we know PA, NA and angle $PAN = VAN + VAP$ Solving for NPA and PN we get

$$NPA = 16^\circ\ 29'\ 51'' = 1^h\ 01^m\ 59^s.4, \quad \text{and} \quad PN = 89^\circ\ 30'\ 23''$$

Subtracting NPA from the R. A. of the Nova and subtracting PN from 90° we have for the position of the Nova

$$\text{R. A.} = 18^h\ 44^m\ 50^s.6 \qquad \text{Decl.} = +\ 0^\circ\ 29'\ 37''$$

COMPARISON WITH NAVAL OBSERVATORY POSITION.

	R. A.	Decl.
Naval Observatory, June 1918	$18^h\ 44^m\ 47^s.13$	$+0^\circ\ 29'\ 34''$
My sextant observation	18 44 50.6	0 29 37
Difference	$3^s.47$	$3''$

COMPARISON WITH MY TRANSIT OBSERVATION.

	R. A.	Decl.
My sextant observation	$18^h\ 44^m\ 50^s.6$	$0^\circ\ 29'\ 37''$
My transit observation	18 44 57.7	0 27 20
Difference	$7^s.1$	$2'\ 17''$

J. ERNEST G. YALDEN.

Leonia, N. J.

GENERAL NOTES.

American Astronomical Society.—Professor Joel Stebbins writes that the next meeting of the American Astronomical Society will be held at the Observatory of the University of Michigan, Ann Arbor, about September 1, 1919.

The Focal Length of the 36-inch Refractor.—In the *Publications of the Astronomical Society of the Pacific* for February, 1919, Dr. J. H. Moore calls attention to the fact that the focal length of the Lick 36-inch refractor has been erroneously given in various places as 674 inches (56 feet 2 inches). This evidently refers to the length of the large tube of the telescope, as the correct focal length of the 36-inch lens for the visual rays, determined in the usual way from micrometric measures, is 694 inches (57 feet 10 inches).

The Adolfo Stahl Lectures in Astronomy.—Mr. Adolfo Stahl has made provision for the publication in book form of the two series of Adolfo Stahl Lectures in Astronomy, delivered in San Francisco in the seasons 1916-17 and 1917-18, under the auspices of Astronomical Society of the Pacific. The book is now in press and will be ready for distribution soon. It will be a book of about 240 pages containing twelve lectures which have been revised by their authors. The price of the book will be $2.75 and orders should be sent to Mr. D. S. Richardson, 128 Lick Building, 35 Montgomery Street, San Francisco, California.

Mr. Stahl has generously provided that the proceeds of the sale of the volume shall go to the Society to form a special fund.

β Cygni a Triple System.—The bright star in the head of "The Swan" is a well-known wide double star which, however, reveals no relative motion of the components during the past century. The spectrum of the brighter component is composite and the statement by the Harvard observer is that it "could be explained

on the supposition that the brighter member of the visual double is itself double, one component being a star of the 'second type' (yellow), the other a star of the 'first type' (blue), approaching the second type. Professor Campbell gives the following summary of radial velocities of the brighter component obtained at the Lick Observatory on 25 nights from 1898 to 1918 inclusive:

Period	Velocity	No. of Observations
1898-1901	−25.3 km	5
1904-1907	−24.4	2
1910-1912	−23.2	6
1913-1914	−23.0	6
1917-1918	−21.6	6

These show that the velocity is certainly changing, so that the system is doubtless a triple one.

Stars whose Spectra are Composite.—Stars with composite spectra are those whose spectra present the principal characteristics of two distinct spectral types. Eighty-one such stars have been found in the course of the work of the Henry Draper Memorial at Harvard College Observatory. The composite spectrum was interpreted by Professor Pickering to mean in each case that the stellar source was not a single star, but two stars so close together that they appear as a single star, whose spectra are of quite different types.

Professor Campbell in the February, 1919, number of the *Publications of the Astronomical Society of the Pacific* states that several spectrograms of each of 37 of the Harvard list of stars with composite spectra have been obtained in the course of the regular program of radial velocity determinations at the Lick Observatory and at Santiago, Chile. Twenty-three of these stars have variable radial velocity, indicating that they are binary systems. Although the others show no appreciable variation as yet, it may be because their periods are long or the planes of their orbits are nearly perpendicular to the line of sight. Professor Campbell says: "So far as our spectrographic observations are concerned, there is no reason to doubt that all of the thirty-seven stars are binary systems."

The Size of a "Hydrogen Envelop Star".—Dr. W. Carl Rufus of the Detroit Observatory, Ann Arbor, Michigan, has recently given some estimates of the real size of Campbell's hydrogen envelop star BD. +30°3639, which is a Wolf-Rayet star with a gaseous nebula for an envelop or a planetary nebula with a stellar nucleus. Taking the measured diameter of the hydrogen envelop as 6″, and estimating the parallax from theoretical considerations as 0″.006, the diameter of the envelop comes out at once as 6 ÷ 0.006, or 1000 astronomical units. The radius of the envelop is accordingly about 170 times the distance of Neptune from the sun or one fifty-fifth the distance of the nearest star.

Such an estimate is, of course, very uncertain, on account of the impossibility of measuring so small a parallax. Even if the parallax were ten times as great as estimated, however, we should have here a mass of glowing gas somewhat resembling Laplace's conception of the Solar System in its earlier stages of evolution.

Dr. Rufus estimates the star to be 400 times brighter than the sun.

The Smithsonian Chilean Expedition.—The following extract from Director Abbot's report on the work of the Astrophysical Observatory of the Smithsonian Institution shows the status of the Chilean expedition, which was planned a few years ago for the study of the variations in solar radiation, in connection with similar study at Mount Wilson, California.

"Preparations and arrangements for a South American solar-radiation expedition occupied much of the time of the director and that of the instrument maker. As stated in last year's report, a proposed expedition under the auspices of the Hodgkins fund to observe the solar radiation in the most cloudless region of Chile was temporarily postponed on account of the entry of the United States into war, and the expedition was diverted for a time to Hump Mountain in Western North Carolina. Observations of the solar constant of radiation were made there, when weather permitted, until March, 1918. By that time it had grown to be certain that the site was too cloudy for the work, and, notwithstanding grave difficulties brought about by the war, the expedition was sent to Chile as originally proposed.

"Director A. F. Moore and Assistant L. H. Abbot landed at Antofagasta, Chile, on June 16, 1918, with a large equipment of apparatus and supplies suitable to the investigation. They were greatly aided by the governor of the Province, the United States consul, and others, and the Chile Exploration Co, generously gave them the use of buildings and other valuable facilities at their disused mine at Chorillos, near Calama. Calama is a station on the railroad east of the nitrate desert, on the bank of the River Loa, at latitude N. 22° 28′, longitude W. 68° 56′, altitude 2,250 meters. Manuscript of daily meteorological records of two years, most kindly copied by Dr. Walter Knoche, former director of the Chilean Meteorological Service, lead us to hope for as many as 300 days per year favorable to solar constant work there. The experiments are to be continued daily, as far as possible, for several years. They should furnish meteorologists with a firm basis for estimating the effects of the solar variability on the terrestrial climate."

The Total Eclipse of the Sun, May 29, 1919.—Although the eclipse has one of the longest durations of totality to occur in many years (total eclipse will last almost seven minutes at the middle of the path of totality), yet we have heard very little about plans for observing it. This is perhaps because it occurs so soon after the great war, and partly because of the inaccessibility of observing stations.

By reference to the chart on page 39 (January, 1919, number of POPULAR ASTRONOMY) the reader will see that the path of totality traverses the torrid zone, across South America, the Atlantic Ocean and Africa. The most favorable observing stations will be on the northern coast of Brazil, the St. Paul Islands, Princes Island and the east coast of French Congo. In all of these localities the weather conditions are liable to be bad.

From a private letter we learn that Dr. A. C. D. Crommelin and Mr. Davidson, of the Royal Observatory at Greenwich, England, were "to leave for Brazil on March 8 to view the eclipse of May 29. The special aim is to test the Einstein effect. There is a rich field of stars around the eclipsed sun."

Rear Admiral J. A. Hoogewerff, Superintendent of the U. S. Naval Observatory, writes in response to our inquiry, that the "Naval Observatory has considered the matter of sending an expedition to observe the total solar eclipse of May 28-29, 1919, but on account of prevailing conditions it will not be possible to do so."

From "Terrestrial Magnetism" March 1919, we learn that the Department of Terrestrial Magnetism of the Carnegie institution of Washington is planning special magnetic and allied observations at certain stations inside and outside the shadow belt, and that various magnetic observatories, institutions and individuals have offered their coöperation,

The stations of the Department of Terrestrial Magnetism will be probably: 1. LaPaz, Bolivia; 2. Huancayo (north of the belt of totality); 3. Near Sobral, Brazil; 4. Ile Principe or Libreville, French Congo; 5. Stations outside belt of totality by field parties as found possible.

MYTHOLOGY OF THE CONSTELLATIONS.

From Polaris the Little Bear hangs by his tail,
When wind is blowing, mayhap it's his wail;
The Big Bear follows along his course,
Afar stands Pegasus, the winged horse.
While riding down the Milky Way,
Beware, lest near you Comets stray;
And as you go, keep open eyes
For Serpents there of monstrous size!

The Dragon guarded once a well—
'Twas slain by Cadmus, Ancients tell;
As Phaeton drove the fiery sun
Too near the earth, 'twould harm have done.
Had thunderbolt not struck his heart.
The Eagle fears the arrow's dart;
Corvus, the crow, seeks Hydra's death,
The Scorpion's sting would end his breath.

The Dolphin loved the Golden Lyre—
Of its sweet strains, 'twould never tire;
The goddess, Justice, held the Balance—
The Golden Age revered her talents.
Orion, mighty hunter 's there,
And at his feet lies martyred Hare;
From belt his sword hangs by his side,
His Hunting Dogs in patience bide.

The Fishes sport in a Sea of Stars;
Of Taurus 'twere well to keep up the bars,
For Aldebaran glows with fiery light
Through millions of millions of miles of night!
The argonauts sailed from all parts of Greece
To obtain from Aries the Golden Fleece;
Of Castor and Pollux, the time was when
The Romans believed "they were helpers of men."

There stands the giant, Hercules.—
His hands, the lion, had slain with ease;
Here Cepheus and Cassiopeia dwell;
To Andromeda, a cruel fate befell—
Chained to a rock till Perseus came,
Her hand in marriage he did claim;
This "prehistoric knight" fulfilled
His task when Cetus he had killed.

Aquarius holds his dipper afar,
The Northern Cross shows many a star;
The Sisters Seven now dwell on high—
They're daughters of Atlas who holds up the sky.
Corona is the Northern Crown
Of Ariadne of renown;
Capricornus—"worse confusion" still—
The place of "goat" in the heavens must fill!

Norfolk, Virginia, March, 1919. ALICE BERLINGETT.